Discrete Structures: CMPSC 102

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Week 10

Let's Discuss

Key Questions

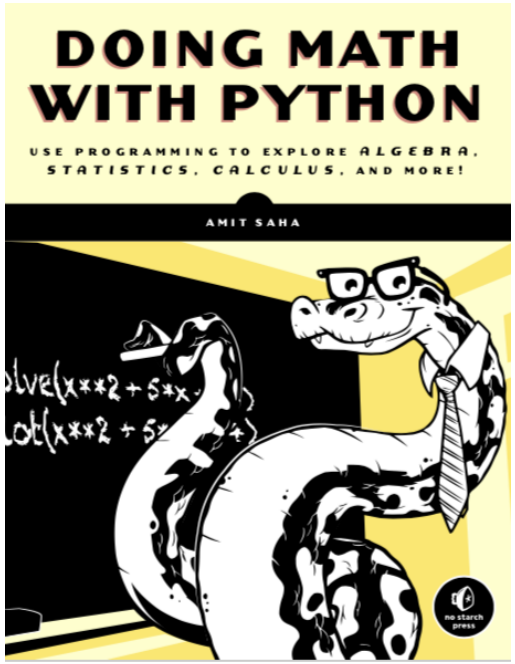
How do I implement data structures to create plots? How do I install such masterful software to do this?!

Learning Objectives

To **remember** and **understand** some concepts about **plots**, and the code used to make them from `matplotlib`.

Where Are We Now?

Saha's Book

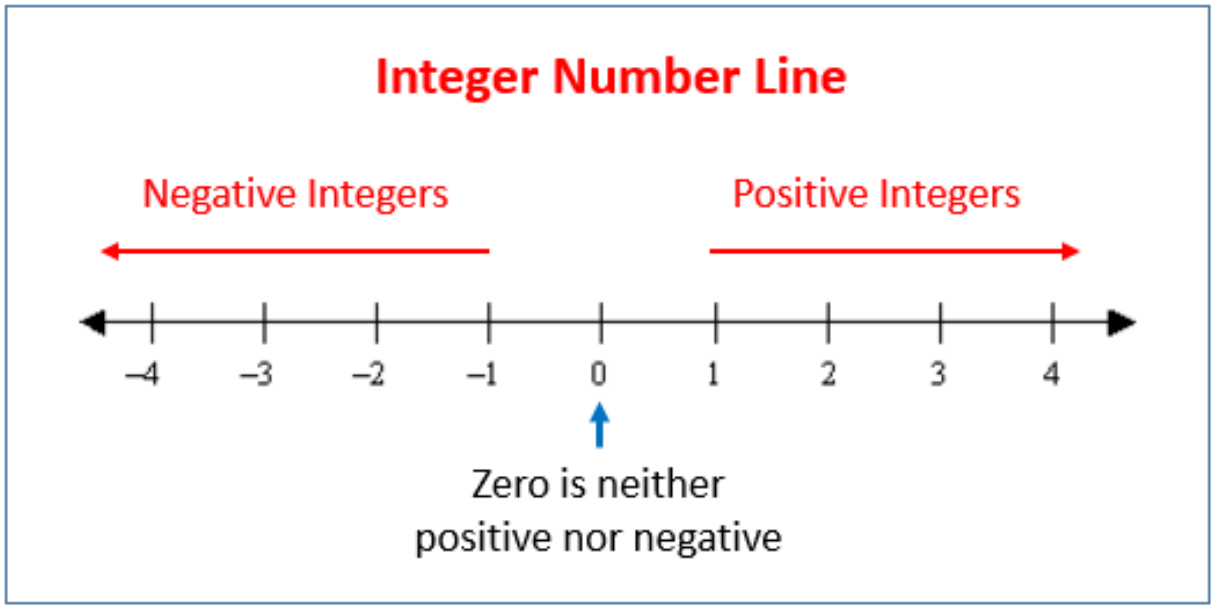


Saha, Chapter 2: Visualizing Data with graphs

- How to present data with graphics
- Plotting basic numbers
- Plotting results from equations
- Plotting all kinds of things!

A Number Line: x

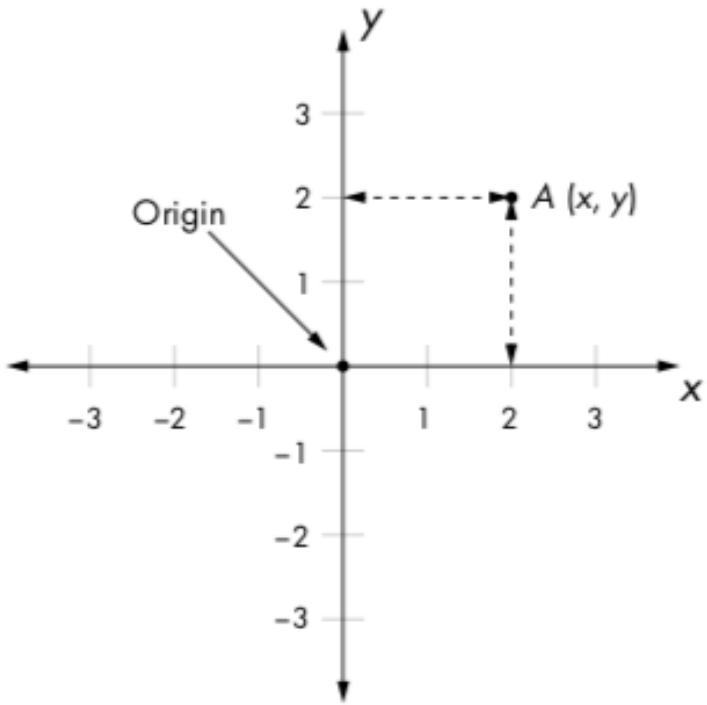
Denoted R



- The x-axis runs horizontally left to right
- The middle of the number line is where $x = 0$
- Left of 0: negative numbers (all kinds of numbers!)
- Right of 0: positive numbers (all kinds of numbers, too!)

Cartesian System, 2-D Coordinates: x and y

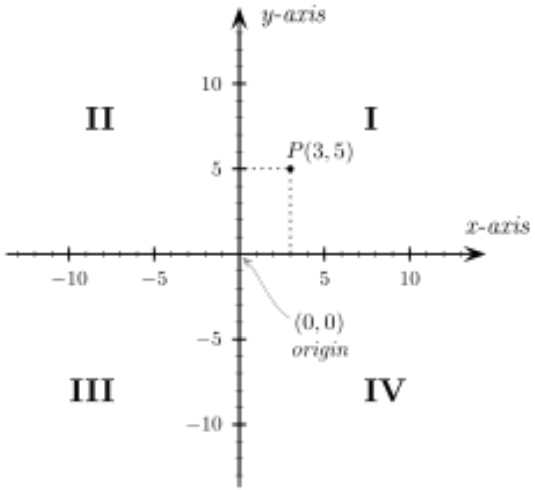
Denoted R^2



- The x-axis runs along the bottom (horizontally left to right)
- The y-axis runs along the side (vertically bottom to top)
- Typically, the $(0, 0)$ point (the origin) is shown where $x = 0$ and $y = 0$

2-D Coordinates: x and y

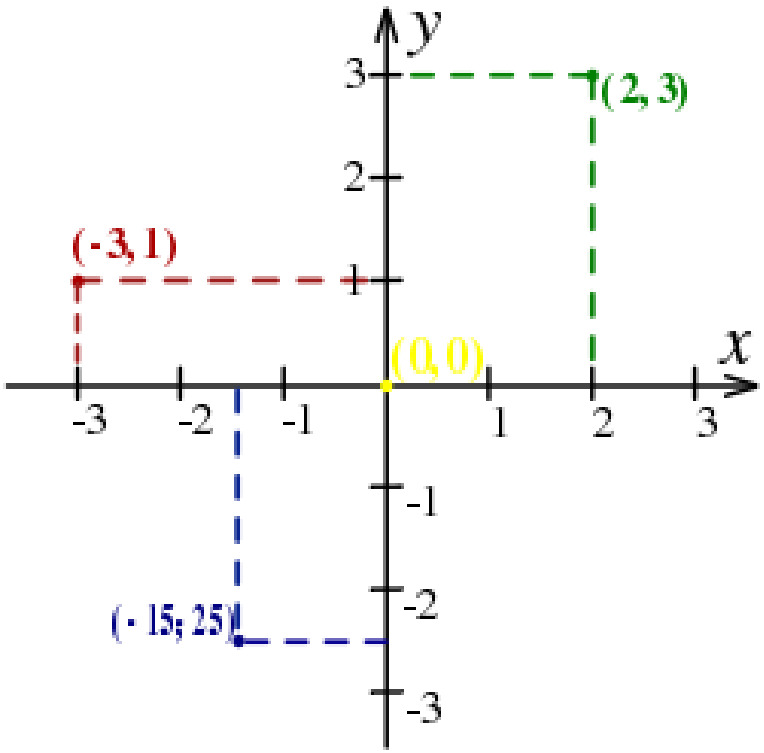
Denoted R^2



- The intersection of the values of x and y creates the 2-D point (called the ordered pair) on the canvas.
- There are four quadrants defined by:
  1. Quadrant I: (x, y)
  2. Quadrant II: $(-x, y)$
  3. Quadrant III: $(-x, -y)$
  4. Quadrant IV: $(x, -y)$

Example Coordinates: x and y

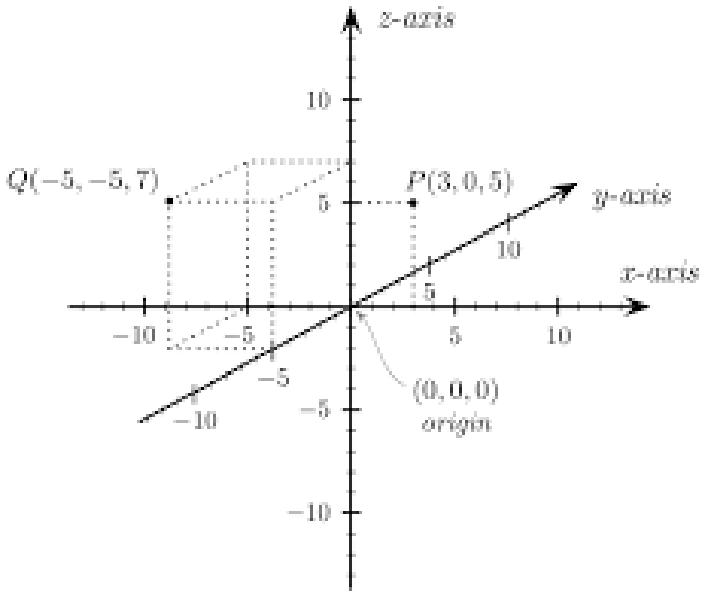
Example plot



- Origin: $(0, 0)$
- Green: $(2, 3)$
- Red: $(-3, 1)$
- Blue: $(-1.5, -2.5)$

3-D Coordinates: x, y, and z

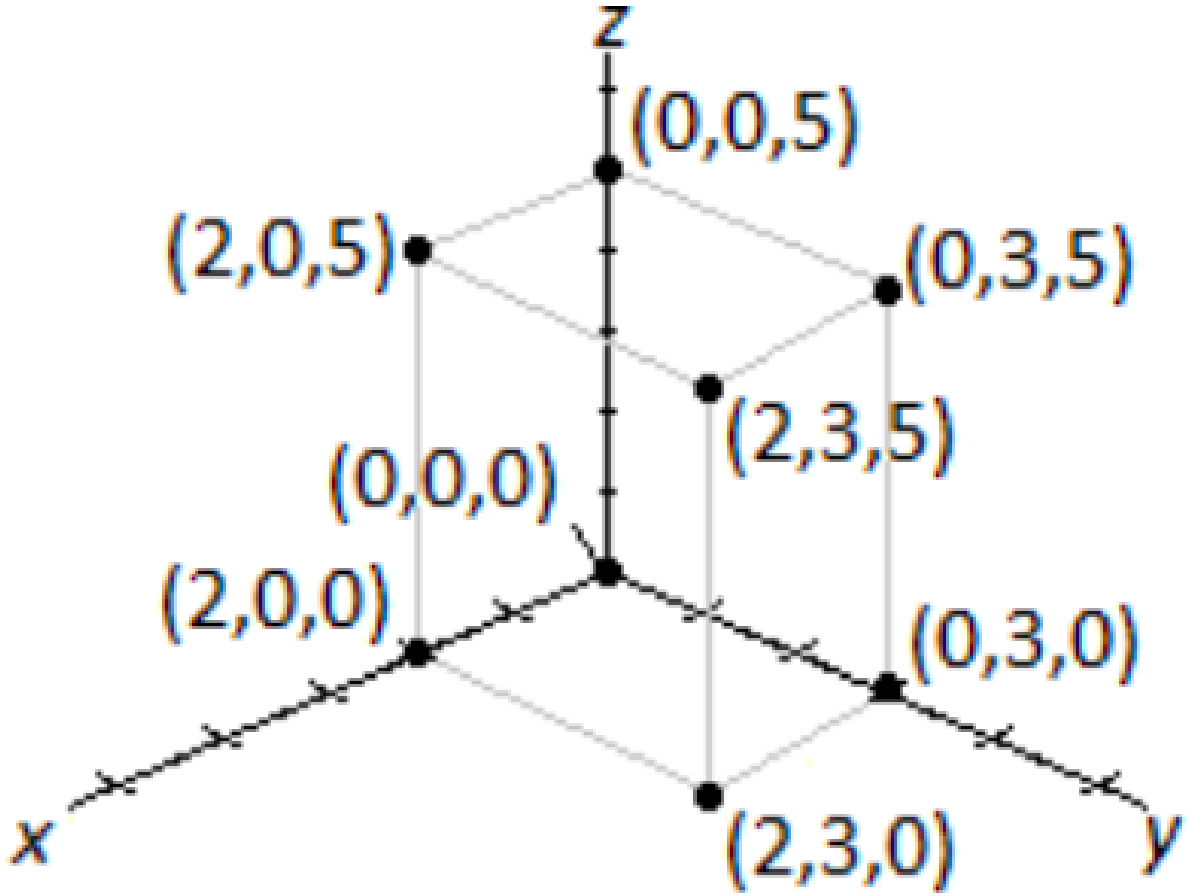
Denoted R^3



- The three number lines are called the x-axis, the y-axis, and the z-axis and are called the *coordinate axes*
- The intersection of the values of x, y and z creates the point defined by the ordered triple on the canvas.
- The z-axis:

3-D Coordinates: x, y, and z

Example plot



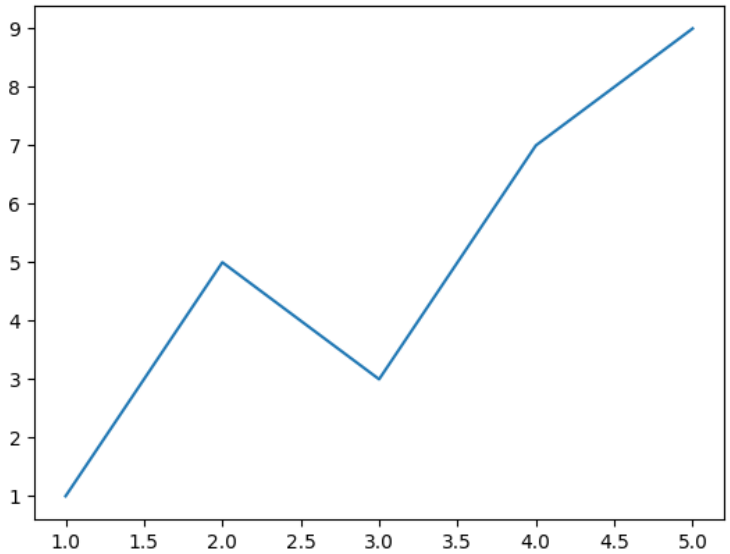
Matplotlib

- Matplotlib is a Python 2D plotting library
- Produces publication quality figures in Python in a variety of hardcopy formats and interactive environments across platforms.
- Allows you to plot your data without much extra coding

Your First Plot

Plot some simple points

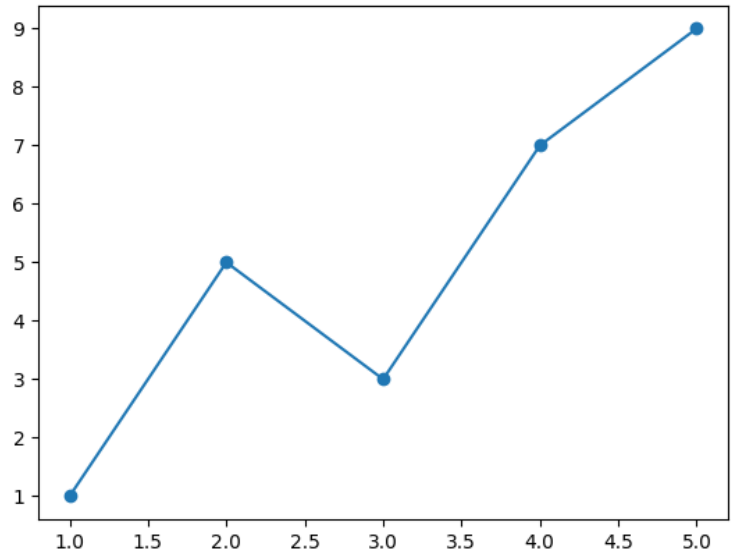
```
from pylab import plot, show #get the library
x_num = [1,2,3,4,5] #def of x
y_num = [1,5,3,7,9] # def of y
plot(x_num, y_num)  # gives mem addr of obj
show() # draw the plot on canvas
```



Gimme Points, Not Lines

Plot some basic numbers using points

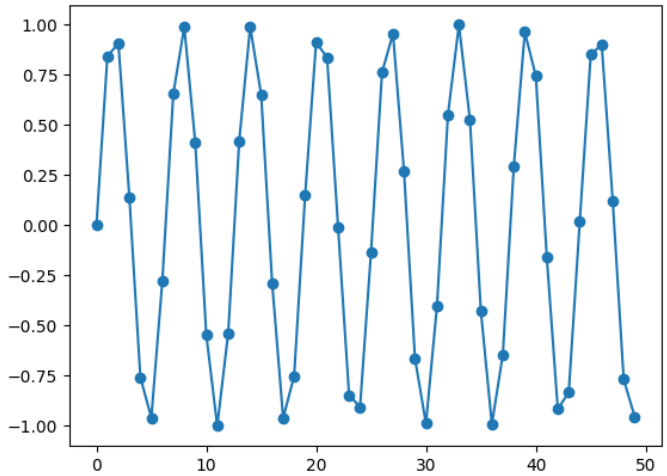
```
from pylab import plot, show #get the library
x_num = [1,2,3,4,5] #def of x
y_num = [1,5,3,7,9] # def of y
plot(x_num, y_num, marker ='o')
# also including 'o', '*', 'x', and '+' as points
show() # draw the plot on canvas
```



Another Amazing Example!

Plot the sin wave

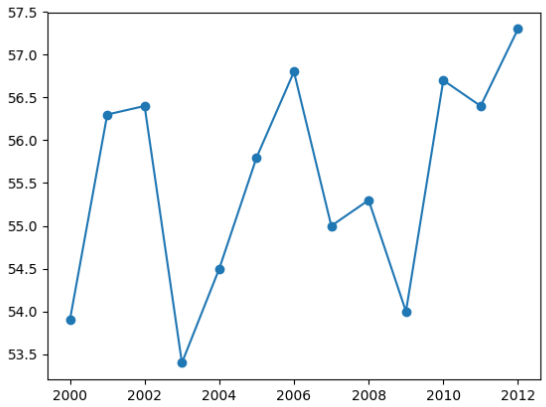
```
from pylab import plot, show #get the library
import math
x_num = [i for i in range(50)]
y_num = [math.sin(i) for i in x_num]
plot(x_num, y_num, marker ='o')
# also including 'o', '*', 'x', and '+' as points
show() # draw the plot on canvas
```



Yet, **Another** Amazing Example!

Plot the temperature in NYC and save the file too!

```
from pylab import plot, show, savefig #note savefig
nyc_temp = [53.9, 56.3, 56.4, 53.4, 54.5, 55.8,
56.8, 55.0, 55.3, 54.0, 56.7, 56.4, 57.3]
years = range(2000, 2013)
plot(years, nyc_temp, marker='o')
# also including 'o', '*', 'x', and '+' as points
savefig('mygraph.png') #save in root directory
show() # draw the plot on canvas
```



Three Plots Together! Amazing!

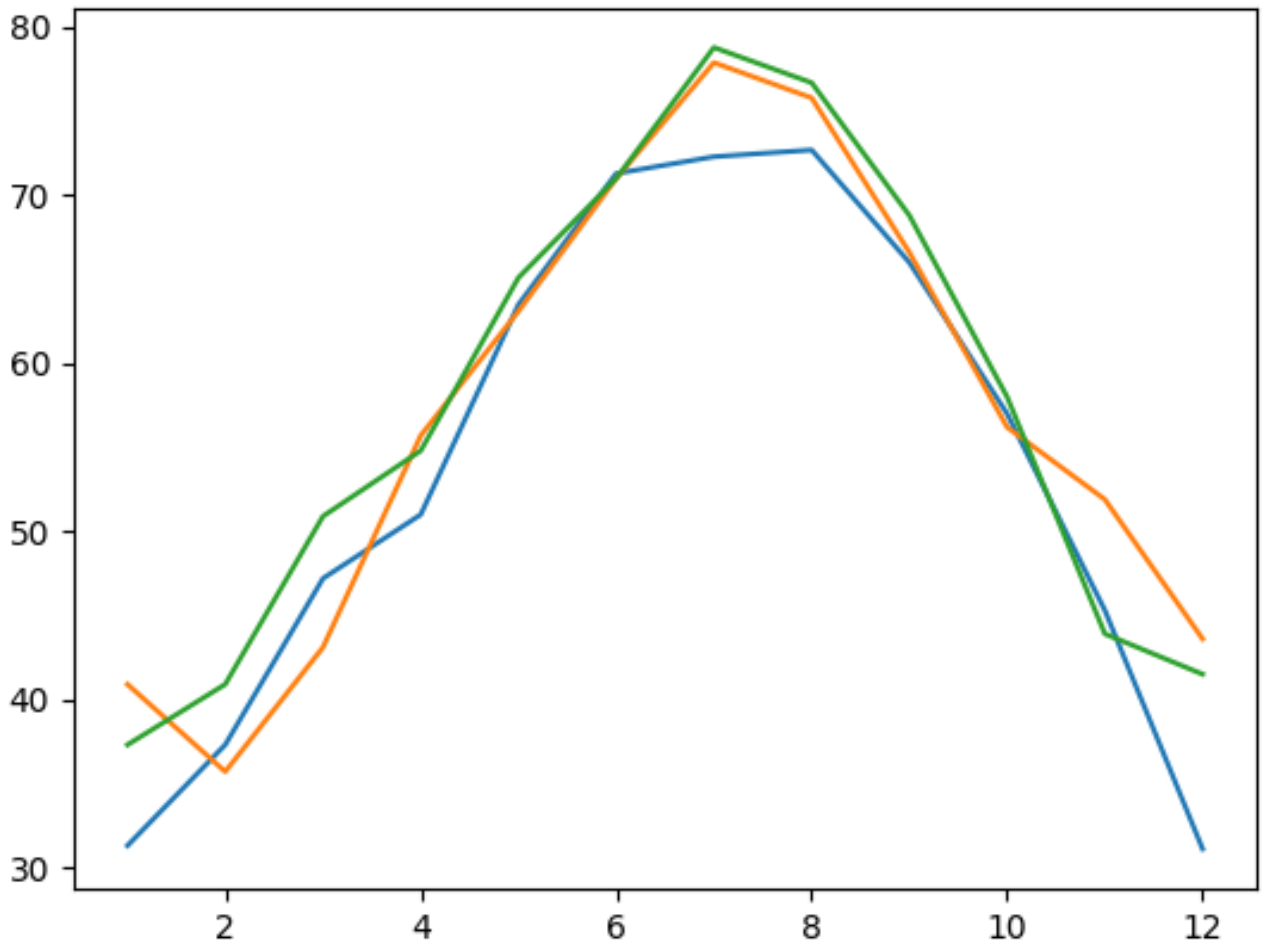
Plot the temperature in NYC aggregated by time

Place in python3 or in a python3 program file

```
from pylab import plot, show, savefig #note savefig
months = range(1, 13)

nyc_temp_2000 = [31.3, 37.3, 47.2, 51.0, 63.5, 71.3,
72.3, 72.7, 66.0, 57.0, 45.3, 31.1]

nyc_temp_2006 = [40.9, 35.7, 43.1, 55.7, 63.1, 71.0,
77.9, 75.8, 66.6, 56.2, 51.9, 43.6]

nyc_temp_2012 = [37.3, 40.9, 50.9, 54.8, 65.1, 71.0,
78.8, 76.7, 68.8, 58.0, 43.9, 41.5]

plot(months, nyc_temp_2000, months, nyc_temp_2006,
months, nyc_temp_2012)
savefig('mygraph.png') #save in root directory
show() # draw the plot on canvas
```

Three Plots Together! Amazing!

Plot the temperature in NYC aggregated by time



Three Plots Together! And a LEGEND Too!

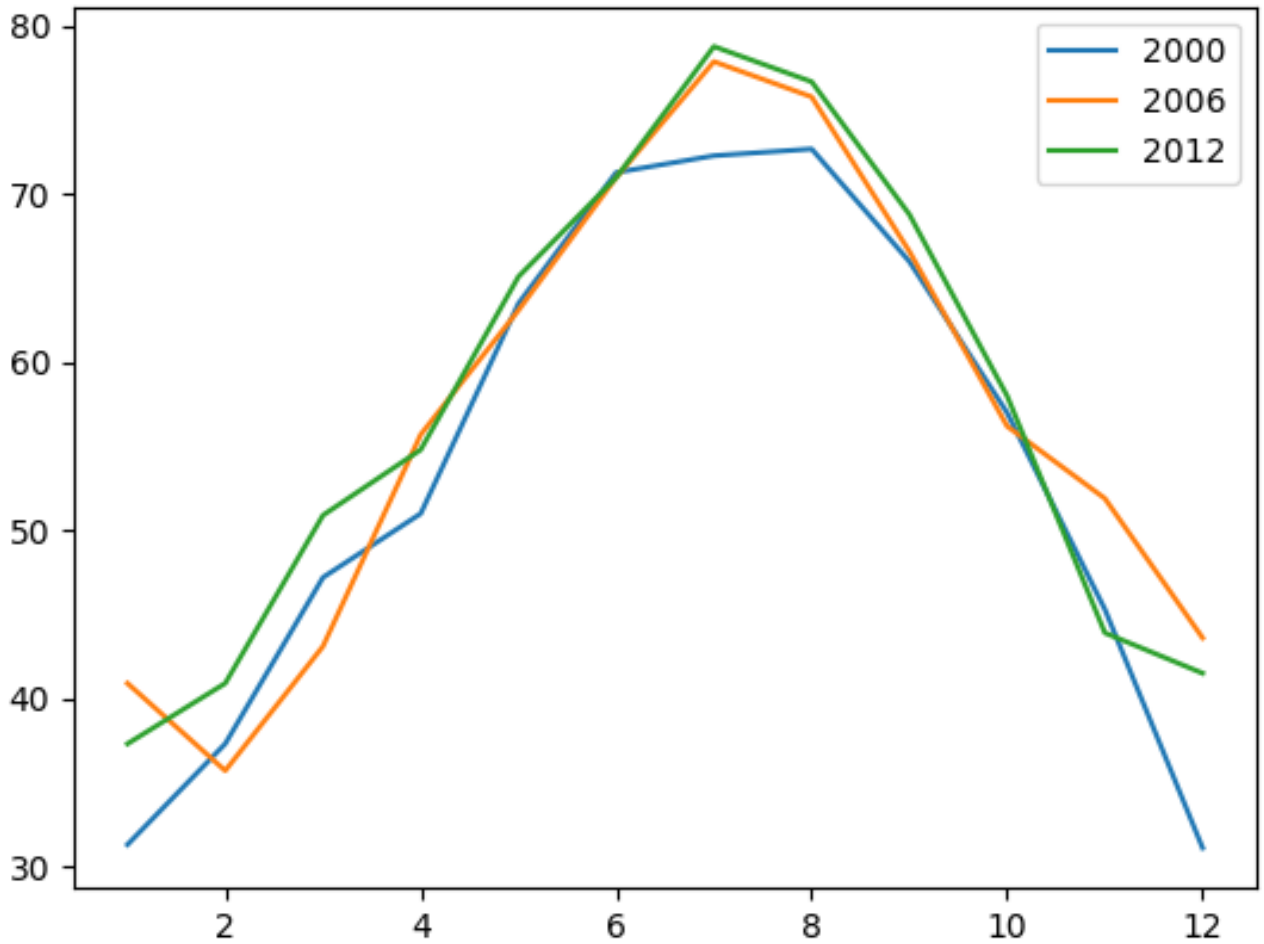
Plot the temperature in NYC aggregated by time

Place in python3 or in a python3 program file

```
from pylab import plot, show, savefig, legend
months = range(1, 13)
nyc_temp_2000 = [31.3, 37.3, 47.2, 51.0, 63.5, 71.3,
72.3, 72.7, 66.0, 57.0, 45.3, 31.1]

nyc_temp_2006 = [40.9, 35.7, 43.1, 55.7, 63.1, 71.0,
77.9, 75.8, 66.6, 56.2, 51.9, 43.6]

nyc_temp_2012 = [37.3, 40.9, 50.9, 54.8, 65.1, 71.0,
78.8, 76.7, 68.8, 58.0, 43.9, 41.5]

plot(months, nyc_temp_2000, months, nyc_temp_2006,
months, nyc_temp_2012)
legend([2000, 2006, 2012]) # make the legend
savefig('mygraph.png') #save in root directory
show() # draw the plot on canvas
```

Three Plots Together! And a LEGEND Too!

Plot the temperature in NYC aggregated by time



Add Title and Axes Descriptions!

Plot the temperature in NYC aggregated by time

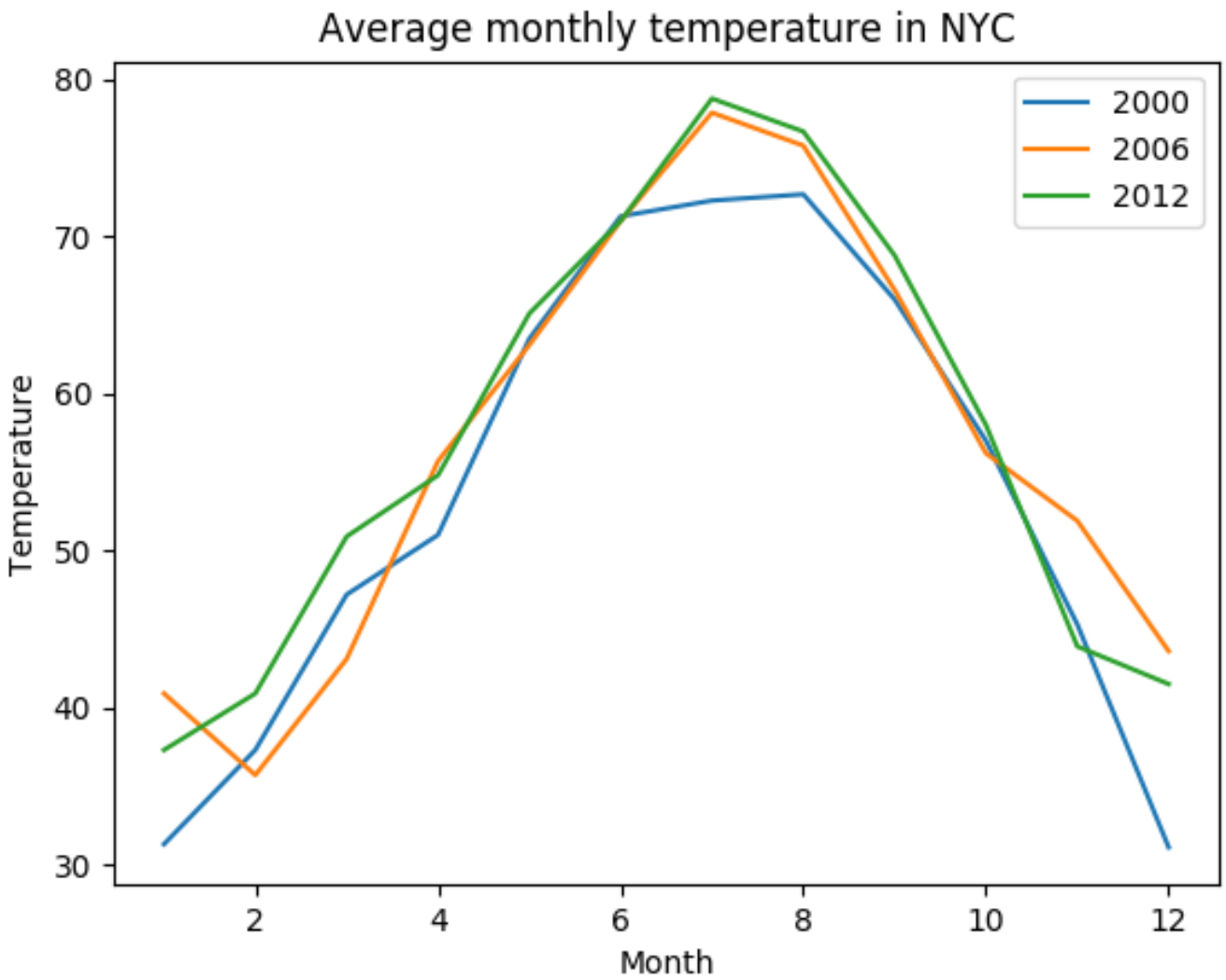
Place in python3 or in a python3 program file

```
from pylab import plot, show, title, savefig, xlabel, ylabel, legend, axis
months = range(1, 13)

nyc_temp_2000 = [31.3, 37.3, 47.2, 51.0, 63.5, 71.3,
72.3, 72.7, 66.0, 57.0, 45.3, 31.1]

nyc_temp_2006 = [40.9, 35.7, 43.1, 55.7, 63.1, 71.0,
77.9, 75.8, 66.6, 56.2, 51.9, 43.6]

nyc_temp_2012 = [37.3, 40.9, 50.9, 54.8, 65.1, 71.0,
78.8, 76.7, 68.8, 58.0, 43.9, 41.5]

plot(months, nyc_temp_2000, months, nyc_temp_2006, months, nyc_temp_2012)
title('Average monthly temperature in NYC')
xlabel('Month') #x-axis label
ylabel('Temperature') #y-axis label
legend([2000, 2006, 2012]) #legend

savefig('mygraph.png') #save in root directory
show() # draw the plot on canvas
```

Sorry about the fine print. :-(

Add Title and Axes Descriptions!

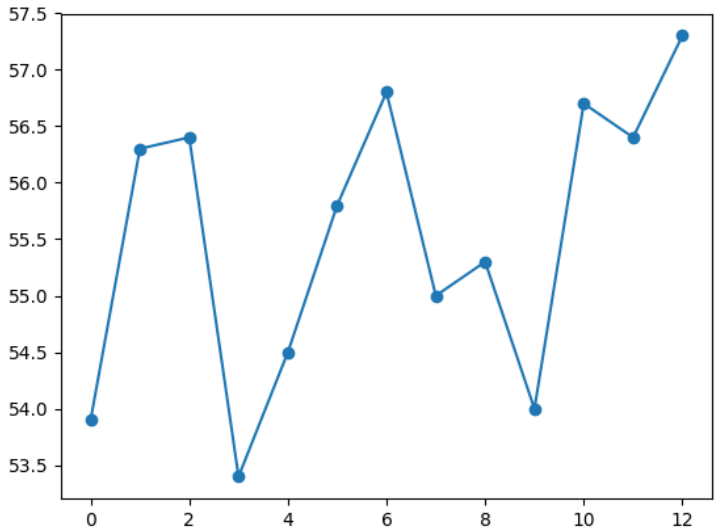
Plot the temperature in NYC aggregated by time



Changing the Field of View

Change the axes of the plot

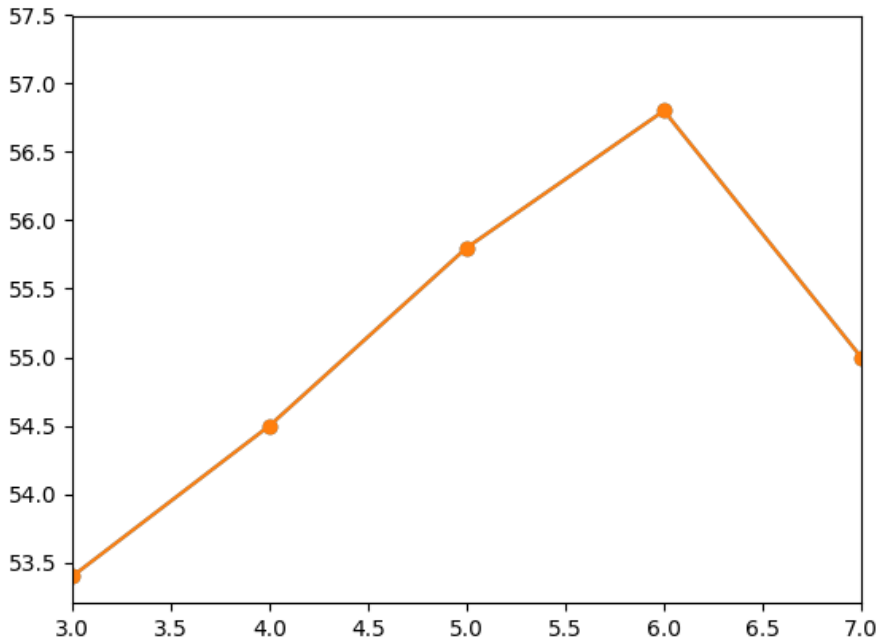
```
nyc_temp = [53.9, 56.3, 56.4, 53.4, 54.5, 55.8,
56.8, 55.0, 55.3, 54.0, 56.7, 56.4, 57.3]
plot(nyc_temp, marker='o')
plt.axis(xmin = 0, xmax = 20, ymin = 0, ymax = 70)
show()
```



COOL!!! Change the axes again to change focus!

Set the x-axis, min and max

```
plot(nyc_temp, marker='o')
plt.axis(xmin = 3, xmax = 7)
show()
```



Plotting the Log Equation

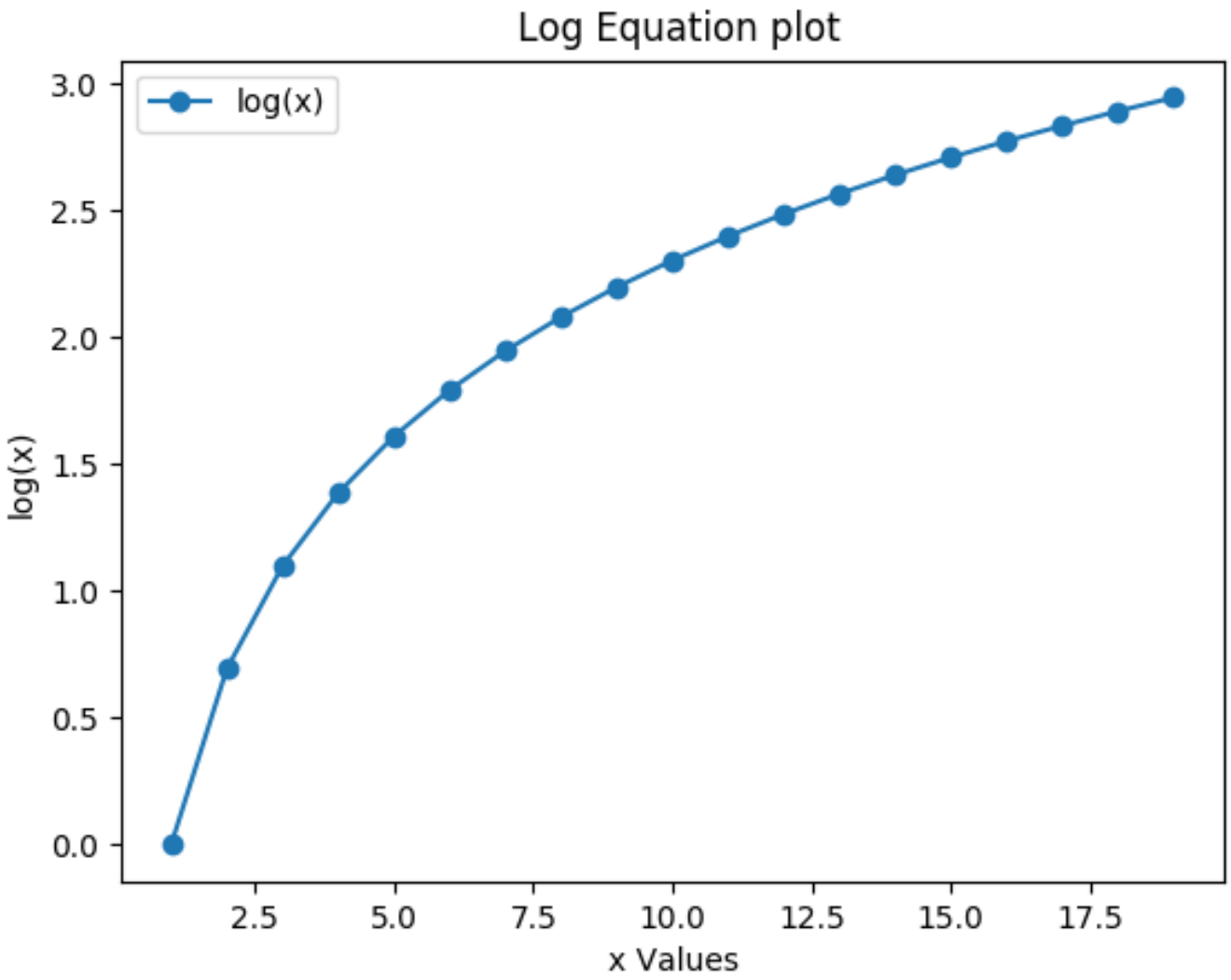
Log Plot

```
from pylab import plot, show, title, savefig, xlabel, ylabel, legend
import math

x = [i for i in range(1,20)] #list comprehension
y = [math.log(i) for i in x] #list comprehension

plot(x,y, marker = 'o')

title(' Log Equation plot')
xlabel('x Values') #x-axis label
ylabel('log(x)') #y-axis label
legend(['log(x)']) #legend

savefig('myLogPlot.png') #save in root directory
show() # draw the plot on canvas
```

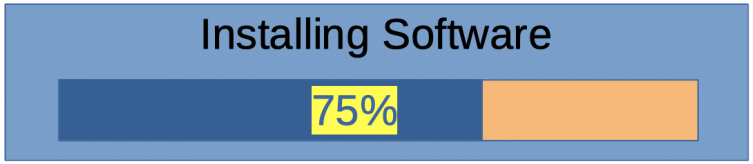
Sorry about the fine print. :-(

The Plotted Log(x)

Plot the temperature in NYC aggregated by time



Setting Up Virtual Environment



Create a project directory (outside of `lassDocs/`)

```
mkdir projects
cd projects
```

Create virtual environment using Python

```
python3 -m venv myenv
```

Activate *myenv* the virtual environment

```
source myenv/bin/activate # unix
myenv\scripts\activate # windows
```

Install Dependencies

```
pip install matplotlib
pip install numpy
```

Creating Plots as files with Matplotlib

- We first need to know that the library is installed on your machine.

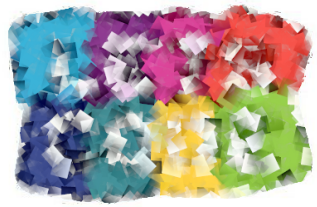
python3

```
from pylab import plot, show
```

- https://matplotlib.org/

Creating Solutions

Check out your `sandbox`!



Koch Snowflakes

Source file: kochSnowflake.py

```
import numpy as np
import matplotlib.pyplot as plt

def koch_snowflake(order, scale=10):
    """  class to drive the program """
    def koch_snowflake_complex(order):
        if order == 0:
            # initial triangle
            angles = np.array([0, 120, 240]) + 90
            return scale / np.sqrt(3) * np.exp(np.deg2rad(angles) * 1j)
        else:
            ZR = 0.5 - 0.5j * np.sqrt(3) / 3
            p1 = koch_snowflake_complex(order - 1)  # start points
            p2 = np.roll(p1, shift=-1)  # end points
            dp = p2 - p1  # connection vectors
            new_points = np.empty(len(p1) * 4, dtype=np.complex128)
            new_points[::4] = p1
            new_points[1::4] = p1 + dp / 3
            new_points[2::4] = p1 + dp * ZR
            new_points[3::4] = p1 + dp / 3 * 2
            return new_points

    # end of koch_snowflake_complex()

    points = koch_snowflake_complex(order)
    x, y = points.real, points.imag
    return x, y

# end of koch_snowflake() class
```

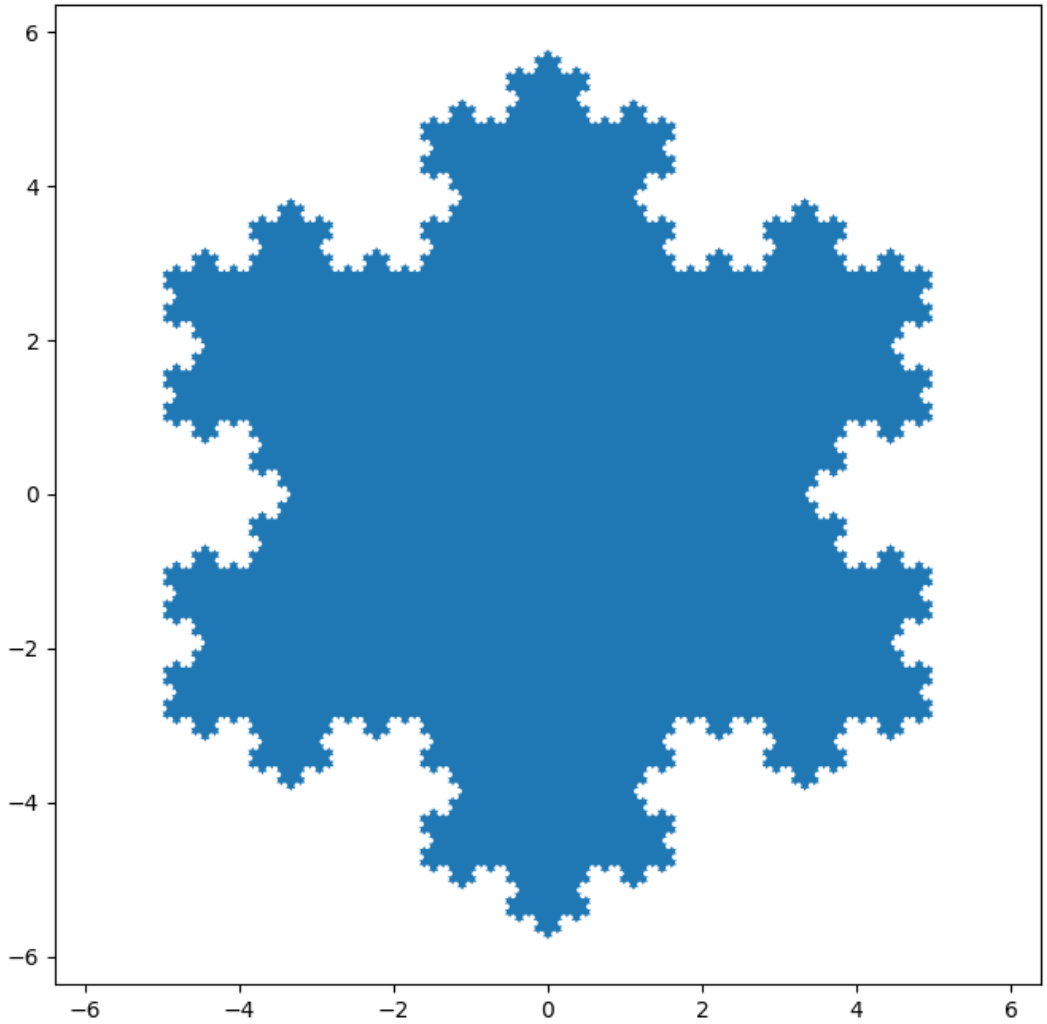
Koch Snowflakes

Source file: kochSnowflake.py

```
def oneStar() -> None:
    """ generate one star """
    x, y = koch_snowflake(order = 5) # thhe order is recursion dept
    plt.figure(figsize=(8, 8))
    plt.axis('equal')
    plt.fill(x, y)
    plt.savefig('koch_oneStar.png')
    #plt.show()
# end of oneStar()

def threeStars() -> None:
    """ generate one star """
    x, y = koch_snowflake(order=2)
    fig, (ax1, ax2, ax3) = plt.subplots(1, 3, figsize=(9, 3),
                                        subplot_kw={'aspect': 'equal'})
    ax1.fill(x, y)
    ax2.fill(x, y, facecolor='lightsalmon', edgecolor='orangered', linewidth=3)
    ax3.fill(x, y, facecolor='none', edgecolor='purple', linewidth=3)

    plt.savefig('koch_threeStars.png')
    #plt.show()

# end of threeStars()

def main() -> None:
    oneStar()
    threeStars()

main()
```

Output: The Koch Snowflake

`Source file: kochSnowflake.py`



Output: The Koch Snowflake

`Source file: kochSnowflake.py`

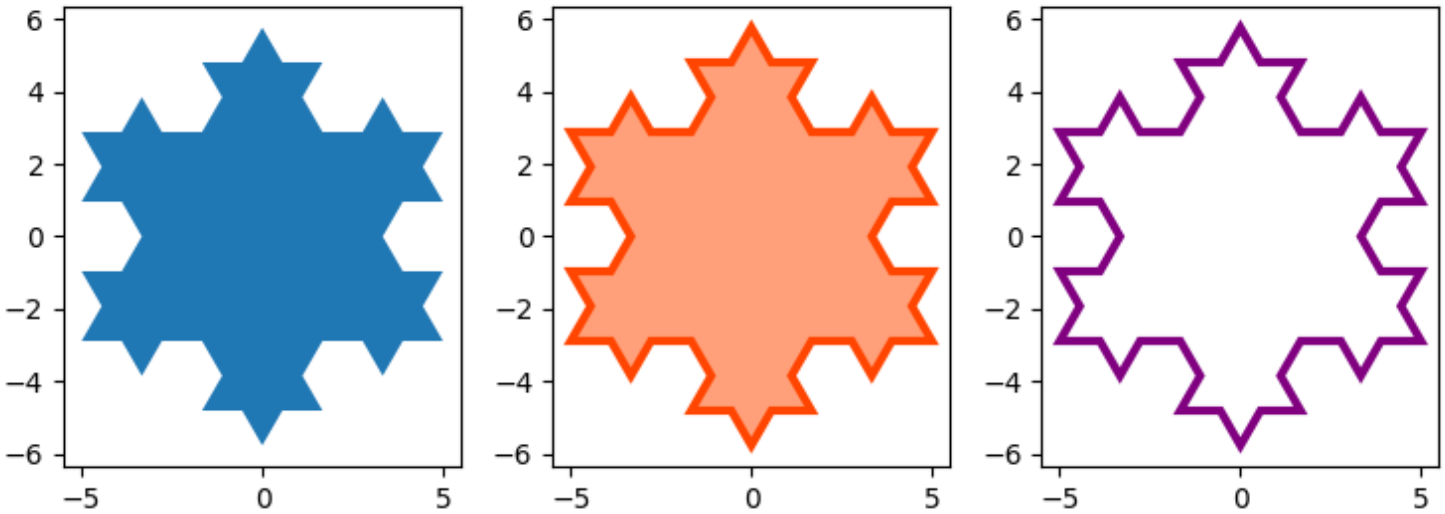


Figure: Three Koch stars as output.

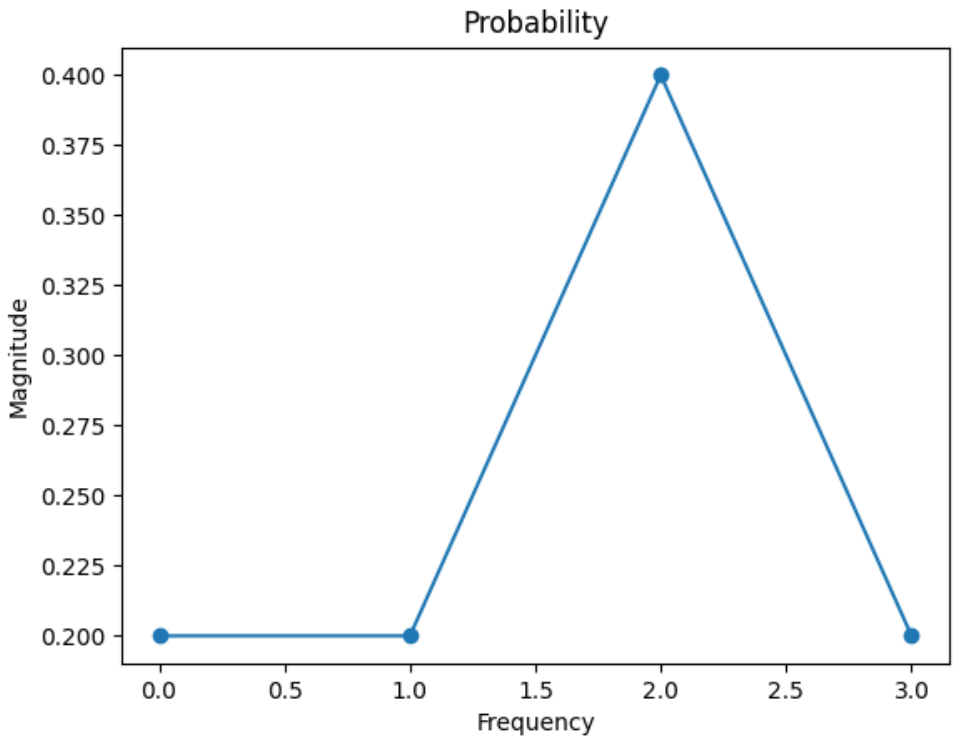
Application: A Frequency Plotter

Source file: charPlot.py

```
# simple plotting tool for frequencies of characters in a string
import matplotlib.pyplot as plt

from pylab import plot, show, title, savefig, xlabel, ylabel, legend

s_str = "hello" # string to study
sCount_dict = {} # save the counts here
# count the letters in the word
for i in s_str:
    if i not in sCount_dict:
        sCount_dict[i] = 1 # add the char to the dictionary with count of one
    else: # this char is already in the dictionary
        sCount_dict[i] = sCount_dict[i] + 1

print(f" Character Counts: {sCount_dict}")

freq_list = [] # list of the frquencies for the chars
for i in sCount_dict:
    freq_list.append(sCount_dict[i]/len(s_str))
print(f" Frequencies: {freq_list}")

y = freq_list
x = [i for i in range(len(freq_list))]
plot(x,y, marker = 'o')
plt.title("Probability")
plt.ylabel('Magnitude')
plt.xlabel('Frequency')
plt.savefig('frequencyPlot.png')
# show()
```

Let's Code

Output: A Frequency Plot



String: *hello there*

Character Counts: {'h': 1, 'e': 1, 'l': 2, 'o': 1}

Frequencies: [0.2, 0.2, 0.4, 0.2]

Let's Code

Now, Go Play With a Plot From the Gallery!

Gallery Website

`https://matplotlib.org/stable/gallery/index.html`