A Tour of Matplotlib

From Bar Charts to XKCD-Style Plots

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About Me

Security architect at Walmart Labs.

Developing security services in Python and Go.

Author of a few open source projects:

- TeXMe: https://github.com/susam/texme
- GitPR: https://github.com/susam/gitpr
- Uncap: https://github.com/susam/uncap

Websites:

- https://twitter.com/susam
- https://github.com/susam
- https://susam.in/

Get Started

```
$ python3 -m venv myenv
$ source myenv/bin/activate
$ pip3 install matplotlib
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>>> plt.plot([2, 3, 5, 7, 11])
>>> plt.show()
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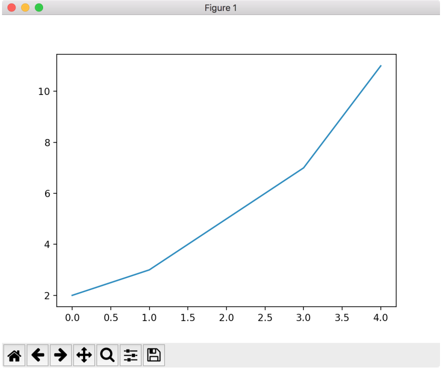
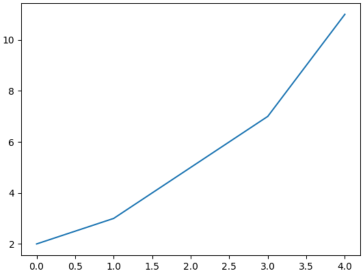


Save Plot to File

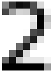
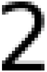
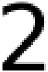
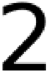
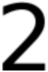
```
import matplotlib.pyplot as plt

plt.plot([2, 3, 5, 7, 11])
plt.savefig('out.png')
```



The default DPI (dots per inch) used to save the image is 100.

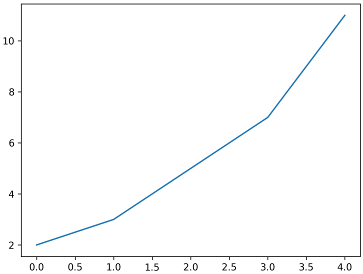
DPI: File Size vs. Quality Tradeoff

DPI	Inches	Pixels	KB	Quality
100	6.4” x 4.8”	640 x 480	15 KB	
200	6.4” x 4.8”	1280 x 960	34 KB	
300	6.4” x 4.8”	1920 x 1440	57 KB	
400	6.4” x 4.8”	2560 x 1920	78 KB	
500	6.4” x 4.8”	3200 x 2400	104 KB	

Save Plot to File: Set DPI to 300

```python
import matplotlib.pyplot as plt

plt.plot([2, 3, 5, 7, 11])
plt.savefig('out.png', dpi=300)
```

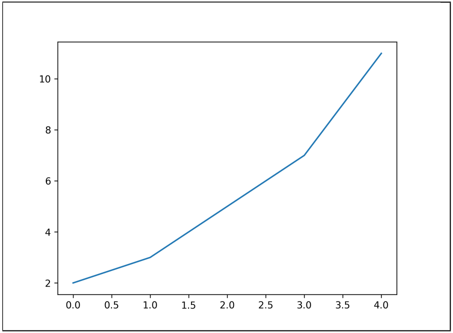


DPI value of 300 provides a good tradeoff between quality and file size.

Default Bounding Box

```
import matplotlib.pyplot as plt

plt.plot([2, 3, 5, 7, 11])
plt.savefig('out.png', dpi=300)
```

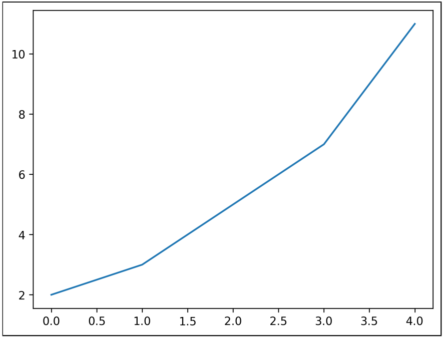


By default there is a lot of padding around the plot. The bounding box is large.

Tight Bounding Box

```
import matplotlib.pyplot as plt

plt.plot([2, 3, 5, 7, 11])
plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



The `bbox_inches='tight'` parameter creates a tight bounding box for the figure.

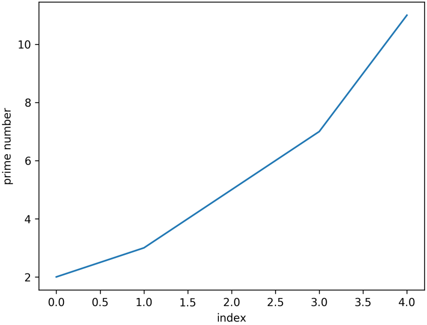
Labels

```
import matplotlib.pyplot as plt

plt.plot([2, 3, 5, 7, 11])

# Label x-axis and y-axis.
plt.xlabel('index')
plt.ylabel('prime number')

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```

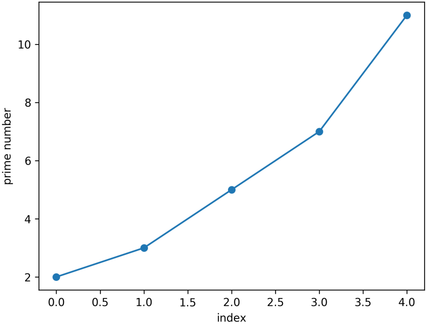


Circle Marker and Solid Line

```
import matplotlib.pyplot as plt

# Format string:
#   'o' for circle marker.
#   '-' for solid line.
plt.plot([2, 3, 5, 7, 11], 'o-')

plt.xlabel('index')
plt.ylabel('prime number')
plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



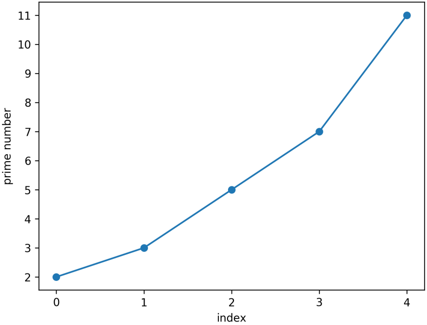
Integer Ticks

```
import matplotlib.pyplot as plt

plt.plot([2, 3, 5, 7, 11], 'o-')
plt.xlabel('index')
plt.ylabel('prime number')

# Place ticks at integer positions.
plt.xticks(range(5))
plt.yticks(range(2, 12))

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



Format String

Syntax:

`[marker][line][color]`

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`[marker][line][color]`

Example:

`'o-k'`

Format String

Syntax:

`[marker][line][color]`

Example:

`'o-k'`

Explanation:

- `'o'` for circle marker
- `'-'` for solid line style
- `'k'` for black color

Format String

Syntax:

`[marker][line][color]`

Example:

`'o-k'`

Explanation:

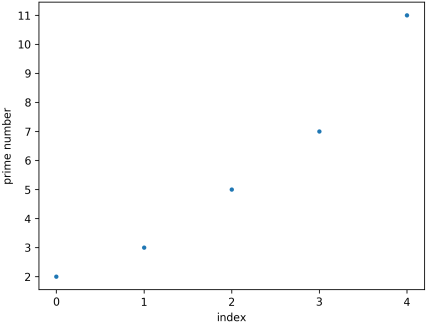
- `'o'` for circle marker
- `'-'` for solid line style
- `'k'` for black color

Usage:

```
plt.plot([2, 3, 5, 7, 11], 'o-k')
```

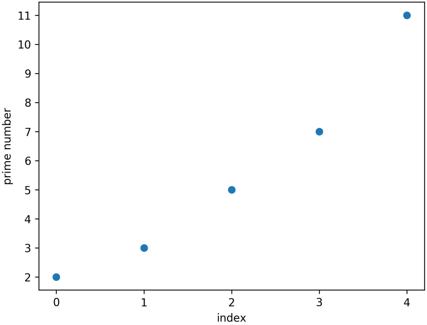
Point Marker

```
import matplotlib.pyplot as plt

# '.' for point marker
plt.plot([2, 3, 5, 7, 11], '.')
plt.xlabel('index')
plt.ylabel('prime number')

plt.xticks(range(5))
plt.yticks(range(2, 12))

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



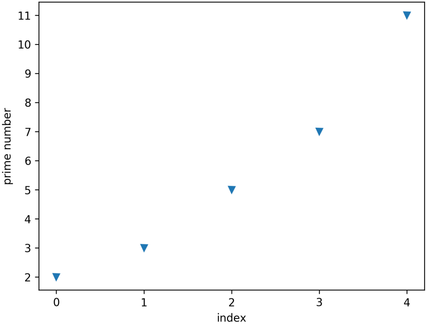
Circle Marker

```
import matplotlib.pyplot as plt

# 'o' for circle marker
plt.plot([2, 3, 5, 7, 11], 'o')
plt.xlabel('index')
plt.ylabel('prime number')

plt.xticks(range(5))
plt.yticks(range(2, 12))

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



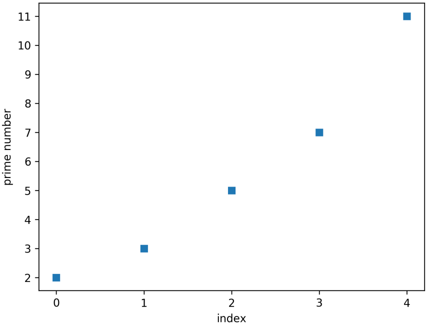
Triangle Down Marker

```
import matplotlib.pyplot as plt

# 'v' for triangle down marker
plt.plot([2, 3, 5, 7, 11], 'v')
plt.xlabel('index')
plt.ylabel('prime number')

plt.xticks(range(5))
plt.yticks(range(2, 12))

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```

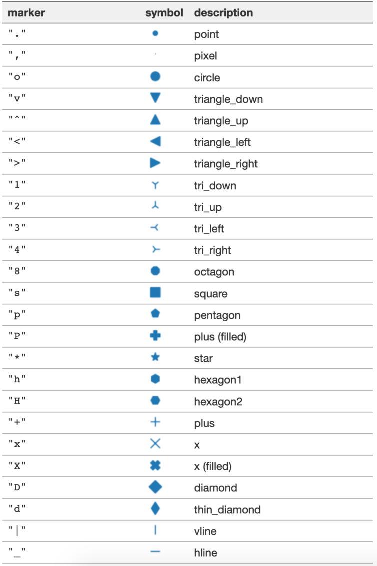


Square Marker

```
import matplotlib.pyplot as plt

# 's' for square marker
plt.plot([2, 3, 5, 7, 11], 's')
plt.xlabel('index')
plt.ylabel('prime number')

plt.xticks(range(5))
plt.yticks(range(2, 12))

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



Markers Reference

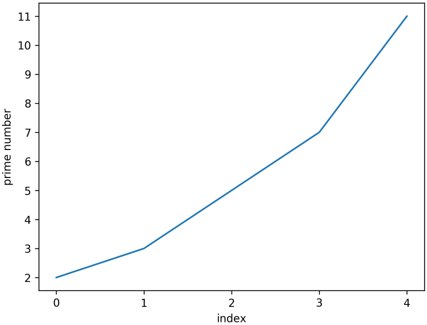


marker	symbol	description
"."	•	point
","	·	pixel
"o"	●	circle
"v"	▼	triangle_down
"^"	▲	triangle_up
"<"	◀	triangle_left
">"	▶	triangle_right
"1"	Y	tri_down
"2"	⅄	tri_up
"3"	≺	tri_left
"4"	≻	tri_right
"8"	⯃	octagon
"s"	■	square
"p"	⬟	pentagon
"P"	✚	plus (filled)
"*"	★	star
"h"	⬢	hexagon1
"H"	⬣	hexagon2
"+"	+	plus
"x"	×	x
"X"	✖	x (filled)
"D"	◆	diamond
"d"	♦	thin_diamond
"|"	|	vline
"_"	—	hline

Source:
https://matplotlib.org/api/markers_api.html

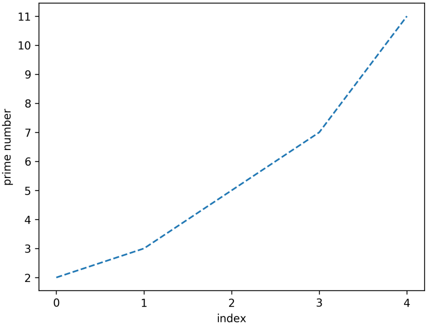
Solid Line Style

```
import matplotlib.pyplot as plt

# '-' for solid line style
plt.plot([2, 3, 5, 7, 11], '-')
plt.xlabel('index')
plt.ylabel('prime number')

plt.xticks(range(5))
plt.yticks(range(2, 12))

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



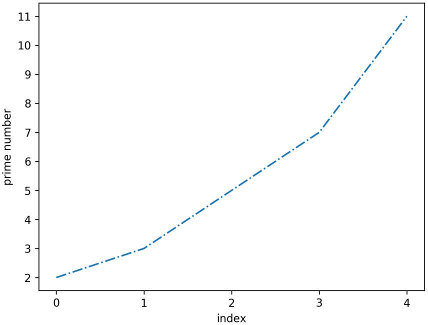
Dashed Line Style

```
import matplotlib.pyplot as plt

# '--' for dashed line style
plt.plot([2, 3, 5, 7, 11], '--')
plt.xlabel('index')
plt.ylabel('prime number')

plt.xticks(range(5))
plt.yticks(range(2, 12))

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



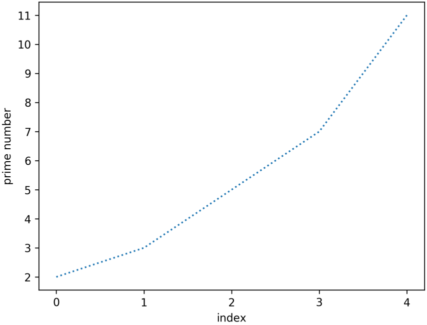
Dash-Dot Line Style

```
import matplotlib.pyplot as plt

# '-.' for dash dot line style
plt.plot([2, 3, 5, 7, 11], '-.')
plt.xlabel('index')
plt.ylabel('prime number')

plt.xticks(range(5))
plt.yticks(range(2, 12))

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```

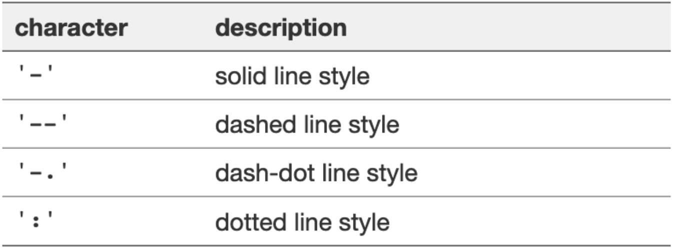


Dotted Line Style

```
import matplotlib.pyplot as plt

# ':' for dotted line style
plt.plot([2, 3, 5, 7, 11], ':')
plt.xlabel('index')
plt.ylabel('prime number')

plt.xticks(range(5))
plt.yticks(range(2, 12))

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



Line Styles Reference

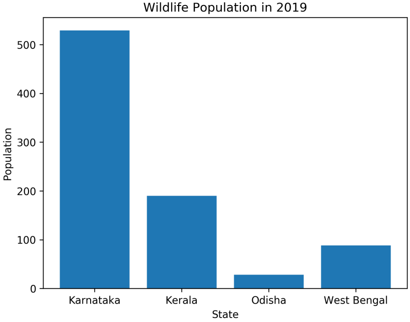


character	description
'-'	solid line style
'--'	dashed line style
'-.'	dash-dot line style
':'	dotted line style

Source: https://matplotlib.org/api/_as_gen/matplotlib.pyplot.plot.html

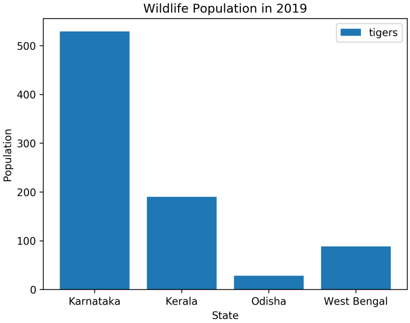
Bar Chart

```
import matplotlib.pyplot as plt

tigers = [529, 190, 28, 88]
states = ['Karnataka', 'Kerala',
          'Odisha', 'West Bengal']

plt.bar(states, tigers)

plt.xlabel('State')
plt.ylabel('Population')
plt.title('Wildlife Population in 2019')

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



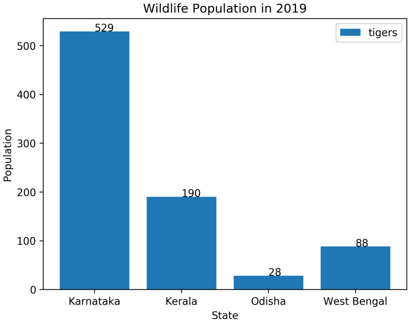
Bar Chart: Legend

```
import matplotlib.pyplot as plt

tigers = [529, 190, 28, 88]
states = ['Karnataka', 'Kerala',
          'Odisha', 'West Bengal']

# Define a label to be used in legend.
plt.bar(states, tigers, label='tigers')

plt.xlabel('State')
plt.ylabel('Population')
plt.title('Wildlife Population in 2019')

# Place a legend.
plt.legend()

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



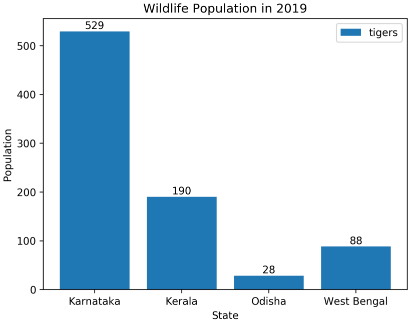
Bar Chart: Using plt.text() to Display Values

```
import matplotlib.pyplot as plt

tigers = [529, 190, 28, 88]
states = ['Karnataka', 'Kerala',
          'Odisha', 'West Bengal']

plt.bar(states, tigers, label='tigers')

plt.xlabel('State')
plt.ylabel('Population')
plt.title('Wildlife Population in 2019')
plt.legend()

for index, value in enumerate(tigers):
    plt.text(index, value, value)

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



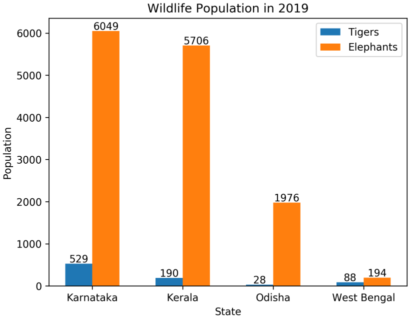
Bar Chart: Center the Values on the Bars

```
import matplotlib.pyplot as plt

tigers = [529, 190, 28, 88]
states = ['Karnataka', 'Kerala',
          'Odisha', 'West Bengal']

plt.bar(states, tigers, label='tigers')

plt.xlabel('State')
plt.ylabel('Population')
plt.title('Wildlife Population in 2019')
plt.legend()

for index, value in enumerate(tigers):
    plt.text(index, value + 5, value, ha='center')

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



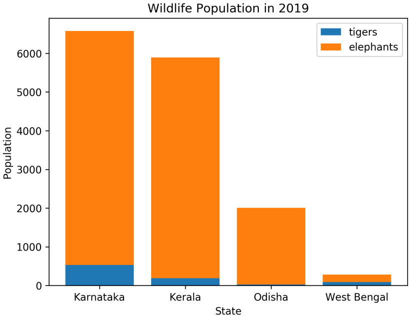
Grouped Bar Chart

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

tigers = [529, 190, 28, 88]
elephants = [6049, 5706, 1976, 194]
states = ['Karnataka', 'Kerala',
          'Odisha', 'West Bengal']

indices = np.arange(len(states))
w = 0.3  # Width of each bar

plt.bar(indices - w / 2, tigers, w, label='Tigers')
plt.bar(indices + w / 2, elephants, w, label='Elephants')

plt.xlabel('State')
plt.ylabel('Population')
plt.title('Wildlife Population in 2019')
plt.legend()

plt.xticks(indices, states)

for index, value in enumerate(tigers):
    plt.text(index - w / 2, value + 30, value, ha='center')

for index, value in enumerate(elephants):
    plt.text(index + w / 2, value + 30, value, ha='center')

plt.savefig('out.png', dpi=300, bbox_inches='tight')
```



Stacked Bar Chart

```
import matplotlib.pyplot as plt

tigers = [529, 190, 28, 88]
elephants = [6049, 5706, 1976, 194]
states = ['Karnataka', 'Kerala',
          'Odisha', 'West Bengal']

plt.bar(states, tigers, label='tigers')
plt.bar(states, elephants, label='elephants',
        bottom=tigers)

plt.xlabel('State')
plt.ylabel('Population')
plt.title('Wildlife Population in 2019')
plt.legend()

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



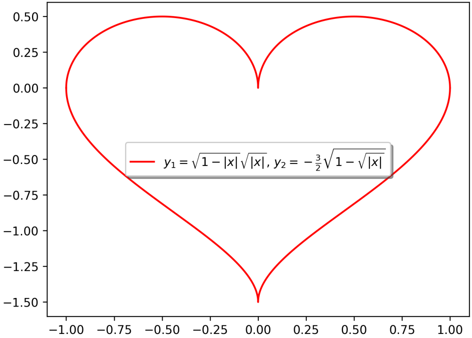
Heart Plot: The Equations

$$\begin{aligned} y_1 &= \sqrt{1 - |x|}\sqrt{|x|}, \\ y_2 &= -\frac{3}{2}\sqrt{1 - \sqrt{|x|}}. \end{aligned}$$

See https://github.com/susam/heart for more details.

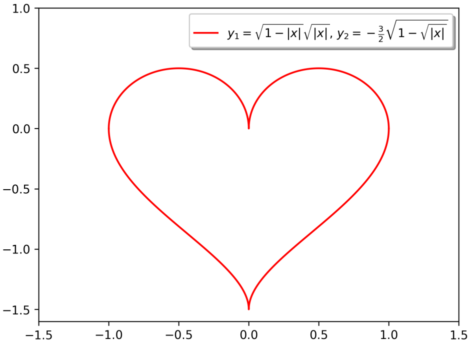
Heart Plot: Plot the Equations

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

label_for_legend = (
    r'$y_1 = \sqrt{1 - |x|} \sqrt{|x|}$, '
    r'$y_2 = -\frac{3}{2} \sqrt{1 - \sqrt{|x|}}$'
)

x = np.linspace(-1, 1, 10001)
y1 = np.sqrt(1 - np.abs(x)) * np.sqrt(np.abs(x))
y2 = (-3 / 2) * np.sqrt(1 - np.sqrt((np.abs(x))))

plt.plot(x, y1, 'r', label=label_for_legend)
plt.plot(x, y2, 'r')
plt.legend(shadow=True)

plt.savefig('out.png', dpi=300, bbox_inches='tight')
```



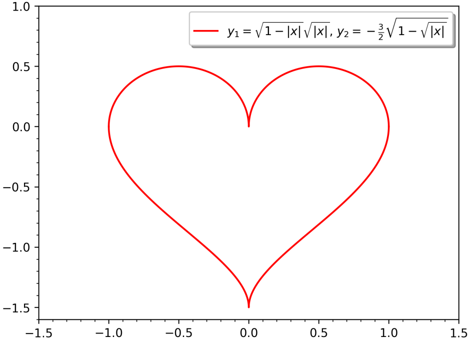
Heart Plot: X and Y Limits

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

label_for_legend = (
    r'$y_1 = \sqrt{1 - |x|} \sqrt{|x|}$, '
    r'$y_2 = -\frac{3}{2} \sqrt{1 - \sqrt{|x|}}$'
)

x = np.linspace(-1, 1, 10001)
y1 = np.sqrt(1 - np.abs(x)) * np.sqrt(np.abs(x))
y2 = (-3 / 2) * np.sqrt(1 - np.sqrt((np.abs(x))))

plt.plot(x, y1, 'r', label=label_for_legend)
plt.plot(x, y2, 'r')
plt.legend(shadow=True)

# Set wider x-limit and y-limit.
plt.xlim([-1.5, 1.5])
plt.ylim([-1.6, 1.0])

plt.savefig('out.png', dpi=300, bbox_inches='tight')
```



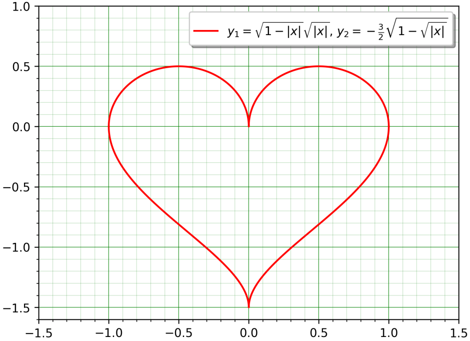
Heart Plot: Major and Minor Tick Locations

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

label_for_legend = (
    r'$y_1 = \sqrt{1 - |x|} \sqrt{|x|}$, '
    r'$y_2 = -\frac{3}{2} \sqrt{1 - \sqrt{|x|}}$'
)

x = np.linspace(-1, 1, 10001)
y1 = np.sqrt(1 - np.abs(x)) * np.sqrt(np.abs(x))
y2 = (-3 / 2) * np.sqrt(1 - np.sqrt((np.abs(x))))

plt.plot(x, y1, 'r', label=label_for_legend)
plt.plot(x, y2, 'r')
plt.legend(shadow=True)

# Set wider x-limit and y-limit.
plt.xlim([-1.5, 1.5])
plt.ylim([-1.6, 1.0])

ax = plt.gca()

# Set major and minor tick loations on the axes.
ax.xaxis.set_major_locator(mpl.ticker.MultipleLocator(0.5))
ax.xaxis.set_minor_locator(mpl.ticker.MultipleLocator(0.1))
ax.yaxis.set_major_locator(mpl.ticker.MultipleLocator(0.5))
ax.yaxis.set_minor_locator(mpl.ticker.MultipleLocator(0.1))

plt.savefig('out.png', dpi=300, bbox_inches='tight')
```



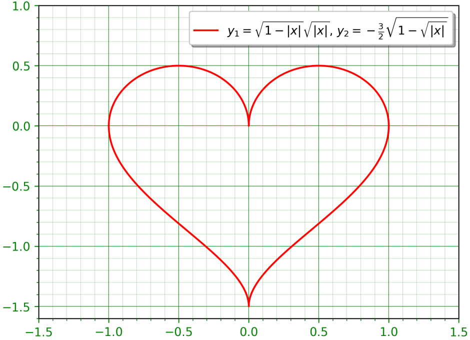
Heart Plot: Green Color Grid

```
# Draw grid lines in green color.
plt.grid(which='major', color='g', linewidth='0.4')
plt.grid(which='minor', color='g', linewidth='0.1')

plt.savefig('out.png', dpi=300, bbox_inches='tight')
```



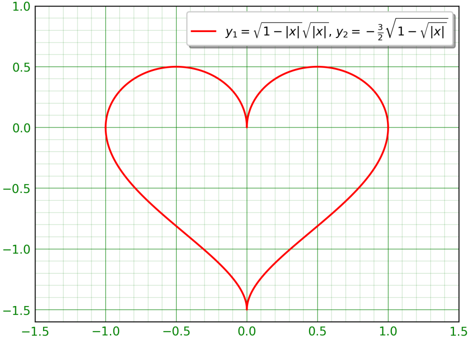
Heart Plot: Green Color Ticks

```
# Draw grid lines in green color.
plt.grid(which='major', color='g', linewidth='0.4')
plt.grid(which='minor', color='g', linewidth='0.1')

# Color the ticks and tick labels green.
plt.tick_params(which='major', colors='g')
plt.tick_params(which='minor', colors='g')

plt.savefig('out.png', dpi=300, bbox_inches='tight')
```



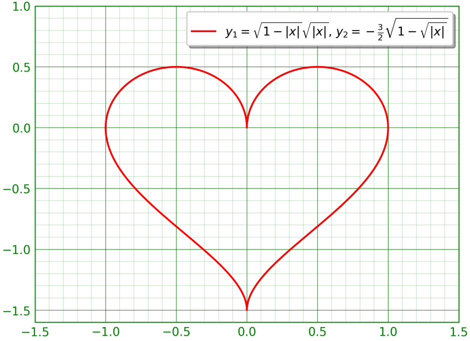
Heart Plot: Zero Tick Length

```
# Draw grid lines in green color.
plt.grid(which='major', color='g', linewidth='0.4')
plt.grid(which='minor', color='g', linewidth='0.1')

# Trim protruding ticks by setting tick length to 0.
plt.tick_params(which='major', colors='g', length=0)
plt.tick_params(which='minor', colors='g', length=0)

plt.savefig('out.png', dpi=300, bbox_inches='tight')
```



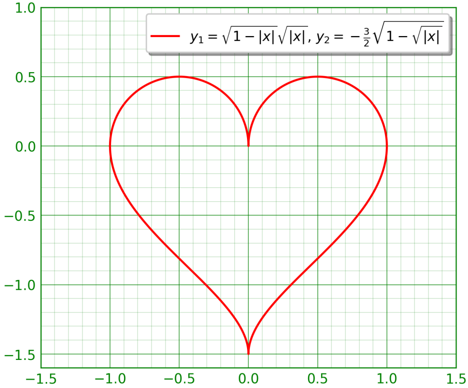
Heart Plot: Green Spines

```
# Draw grid lines in green color.
plt.grid(which='major', color='g', linewidth='0.4')
plt.grid(which='minor', color='g', linewidth='0.1')

# Trim protruding ticks by setting tick length to 0.
plt.tick_params(which='major', colors='g', length=0)
plt.tick_params(which='minor', colors='g', length=0)

# Color spines green.
ax.spines['bottom'].set_color('g')
ax.spines['top'].set_color('g')
ax.spines['right'].set_color('g')
ax.spines['left'].set_color('g')

plt.savefig('out.png', dpi=300, bbox_inches='tight')
```



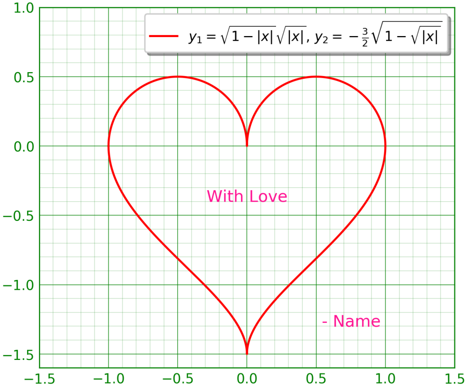
Heart Plot: Equal Aspect Ratio

```
# Draw grid lines in green color.
plt.grid(which='major', color='g', linewidth='0.4')
plt.grid(which='minor', color='g', linewidth='0.1')

# Trim protruding ticks by setting tick length to 0.
plt.tick_params(which='major', colors='g', length=0)
plt.tick_params(which='minor', colors='g', length=0)

# Color spines green.
ax.spines['bottom'].set_color('g')
ax.spines['top'].set_color('g')
ax.spines['right'].set_color('g')
ax.spines['left'].set_color('g')

# Use same scaling to plot units for both axes.
ax.set_aspect('equal')

plt.savefig('out.png', dpi=300, bbox_inches='tight')
```



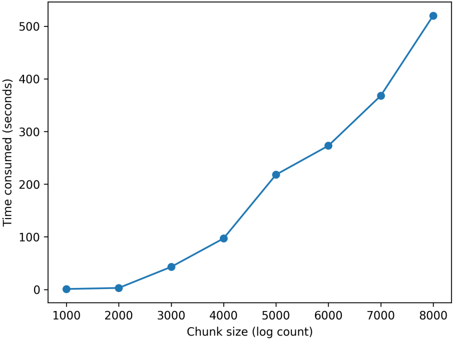
Heart Plot: Text Message

```
# Draw grid lines in green color.
plt.grid(which='major', color='g', linewidth='0.4')
plt.grid(which='minor', color='g', linewidth='0.1')

# Trim protruding ticks by setting tick length to 0.
plt.tick_params(which='major', colors='g', length=0)
plt.tick_params(which='minor', colors='g', length=0)

# Color spines green.
ax.spines['bottom'].set_color('g')
ax.spines['top'].set_color('g')
ax.spines['right'].set_color('g')
ax.spines['left'].set_color('g')

# Use same scaling to plot units for both axes.
ax.set_aspect('equal')

# Add a text message and sign the plot.
kwargs = {'size': 'large', 'color': 'deeppink'}
plt.text(0, -0.4, 'With Love', ha='center', **kwargs)
plt.text(0.54, -1.3, '- Name', **kwargs)

plt.savefig('out.png', dpi=300, bbox_inches='tight')
```



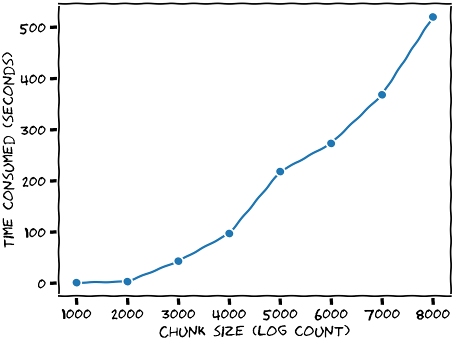
Regular Plot

```
import matplotlib.pyplot as plt

logs = [1000, 2000, 3000, 4000,
        5000, 6000, 7000, 8000]

time = [1, 3, 43, 97, 218, 273,
        368, 520]

plt.plot(logs, time, 'o-')
plt.xlabel('Chunk size (log count)')
plt.ylabel('Time consumed (seconds)')

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



XKCD-Style Plot

```
import matplotlib.pyplot as plt

# Turn on XKCD sketch-style drawing.
plt.xkcd()

logs = [1000, 2000, 3000, 4000,
        5000, 6000, 7000, 8000]

time = [1, 3, 43, 97, 218, 273,
        368, 520]

plt.plot(logs, time, 'o-')
plt.xlabel('Chunk size (log count)')
plt.ylabel('Time consumed (seconds)')

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



XKCD-Style Plot: Font: Humor Sans

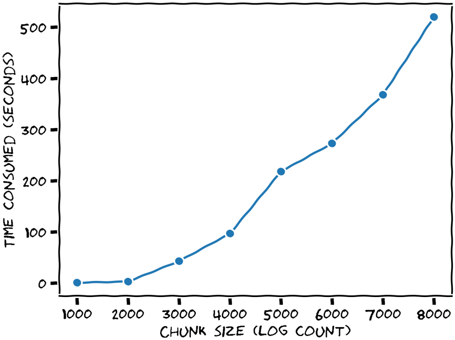
Install **Humor Sans** font for best results.

After installing the font, remove Matplotlib cache
to force rebuilding of font list.

```
# On macOS
brew tap homebrew/cask-fonts
brew cask install font-humor-sans
rm -rf ~/.matplotlib

# On Debian, Ubuntu, etc.
apt-get update
apt-get install fonts-humor-sans
rm -rf ~/.cache/matplotlib
```

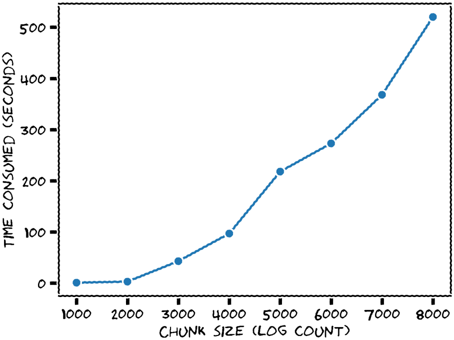
XKCD-Style Plot: Default Parameters

```
import matplotlib.pyplot as plt

plt.xkcd(scale=1, length=100,
         randomness=2)

logs = [1000, 2000, 3000, 4000,
        5000, 6000, 7000, 8000]

time = [1, 3, 43, 97, 218, 273,
        368, 520]

plt.plot(logs, time, 'o-')
plt.xlabel('Chunk size (log count)')
plt.ylabel('Time consumed (seconds)')

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



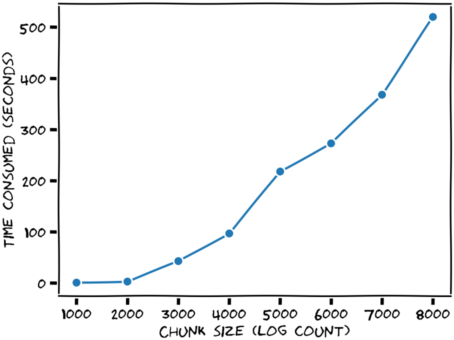
XKCD-Style Plot: `scale=5`

```
import matplotlib.pyplot as plt

plt.xkcd(scale=5)

logs = [1000, 2000, 3000, 4000,
        5000, 6000, 7000, 8000]

time = [1, 3, 43, 97, 218, 273,
        368, 520]

plt.plot(logs, time, 'o-')
plt.xlabel('Chunk size (log count)')
plt.ylabel('Time consumed (seconds)')

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



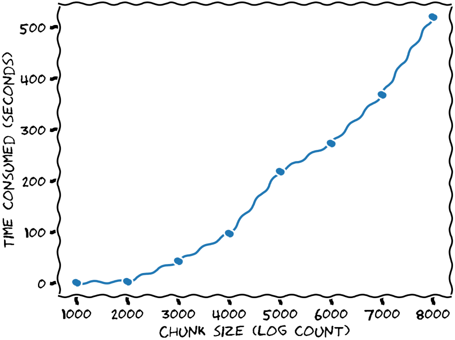
XKCD-Style Plot: `scale=0.2`

```
import matplotlib.pyplot as plt

plt.xkcd(scale=0.2)

logs = [1000, 2000, 3000, 4000,
        5000, 6000, 7000, 8000]

time = [1, 3, 43, 97, 218, 273,
        368, 520]

plt.plot(logs, time, 'o-')
plt.xlabel('Chunk size (log count)')
plt.ylabel('Time consumed (seconds)')

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



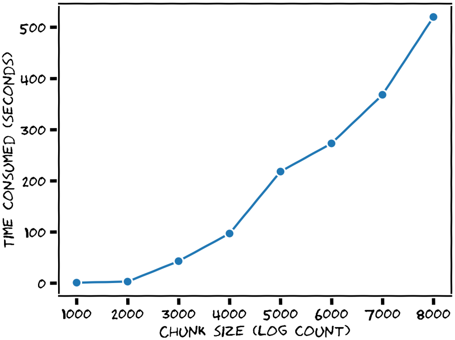
XKCD-Style Plot: `length=20`

```
import matplotlib.pyplot as plt

plt.xkcd(length=20)

logs = [1000, 2000, 3000, 4000,
        5000, 6000, 7000, 8000]

time = [1, 3, 43, 97, 218, 273,
        368, 520]

plt.plot(logs, time, 'o-')
plt.xlabel('Chunk size (log count)')
plt.ylabel('Time consumed (seconds)')

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



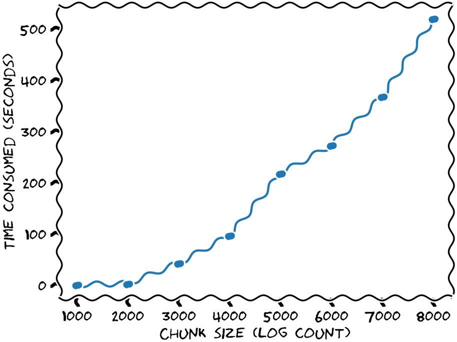
XKCD-Style Plot: `length=500`

```
import matplotlib.pyplot as plt

plt.xkcd(length=500)

logs = [1000, 2000, 3000, 4000,
        5000, 6000, 7000, 8000]

time = [1, 3, 43, 97, 218, 273,
        368, 520]

plt.plot(logs, time, 'o-')
plt.xlabel('Chunk size (log count)')
plt.ylabel('Time consumed (seconds)')

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



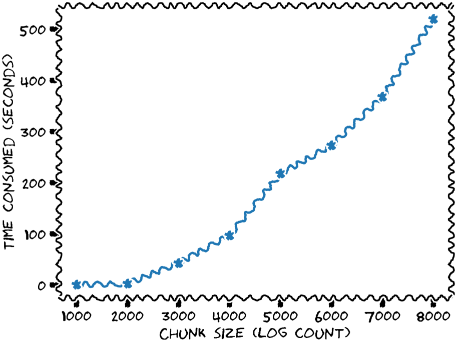
XKCD-Style Plot: `randomness=1`

```
import matplotlib.pyplot as plt

plt.xkcd(scale=10, randomness=1)

logs = [1000, 2000, 3000, 4000,
        5000, 6000, 7000, 8000]

time = [1, 3, 43, 97, 218, 273,
        368, 520]

plt.plot(logs, time, 'o-')
plt.xlabel('Chunk size (log count)')
plt.ylabel('Time consumed (seconds)')

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



XKCD-Style Plot: randomness=10

```
import matplotlib.pyplot as plt

plt.xkcd(scale=10, randomness=10)

logs = [1000, 2000, 3000, 4000,
        5000, 6000, 7000, 8000]

time = [1, 3, 43, 97, 218, 273,
        368, 520]

plt.plot(logs, time, 'o-')
plt.xlabel('Chunk size (log count)')
plt.ylabel('Time consumed (seconds)')

plt.savefig('out.png', dpi=300,
            bbox_inches='tight')
```



Thank You