📊 Python Matplotlib

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1. Basic Plotting Workflow

Almost every plot follows this code structure:

```python
import matplotlib.pyplot as plt

# Defines data x
# Defines corresponding function y = f(x)

plt.plot(x, y)          # Create plot
plt.title("Title")      # Add title
plt.xlabel("X label")
plt.ylabel("Y label")
plt.show()              # Display plot
```

Key idea:
Matplotlib works by **building a figure step-by-step**, then displaying it.

Function `plt.plot()` creates a graph between 2 argument variables.

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2. Common Charts

- Line chart
- Bar chart (vertical & horizontal)
- Scatter plot
- Histogram
- Pie chart
- 3D plot
- Subplot (multiple plots in one figure)

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3. Line Plot

Plot the y axis versus x axis as lines and/or markers.

Function `plt.plot()`

Purpose:

Used to visualize:

- GDP growth over time
- Inflation trends
- Stock prices
- Economic indicators by year/quarter

Function:
The command syntax:

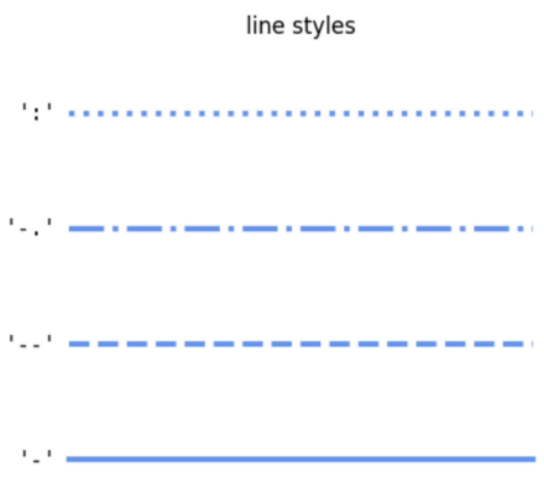
```
plt.plot([x], y, [fmt], data=None, **kwargs)
```

- `fmt` : **format string** of how the line is drawn. (explained later in section Use Format String)
- `data` : the **label** or **source** of the data.
- `**kwargs` : **additional keywords arguments** for line styling.

Some line-styling arguents:

```
marker = 'o' # Define the marker character of the plot
label = 'label' # The label of the plot line
color = blue # The color of the plot line
linestyle = '-' # '-' (solid line), '--' (dashed line), ':' (dot line)
linewidth = 1.5 # Define the line width
```

Marker	Description
"."	point
","	pixel
"o"	circle
"v"	triangle_down
"8"	octagon
"s"	square
"p"	pentagon
"P"	plus (filled)
"*"	star
"h"	hexagon1
"H"	hexagon2
"+"	plus
"x"	x
"X"	x (filled)
"D"	diamond



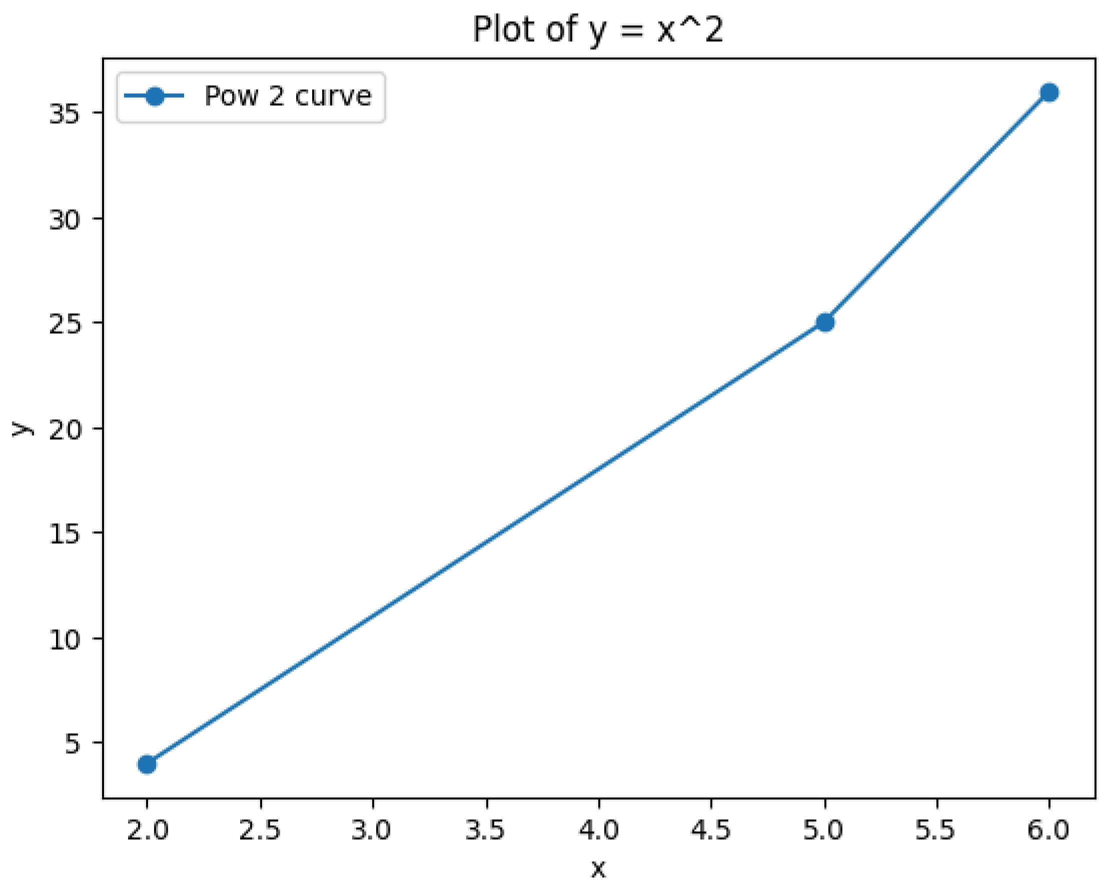
- [color]

- ‘b’ – blue
- ‘g’ – green
- ‘r’ – red
- ‘c’ – cyan
- ‘m’ – magenta
- ‘y’ – yellow
- ‘b’ – black
- ‘w’ – white
- #rrggbb – RGB

Example:

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

# Define x and y = f(x) = x^2
x = np.array([2, 5, 6])
y = x ** 2

# Prepare the line, with marker '0', and line label
plt.plot(x, y, marker='o', color=blue, label="Pow 2 curve")
plt.title("Plot of y = x^2")
plt.xlabel("x")
plt.ylabel("y")
plt.legend() # Display the line label note
plt.show()
```

Output:

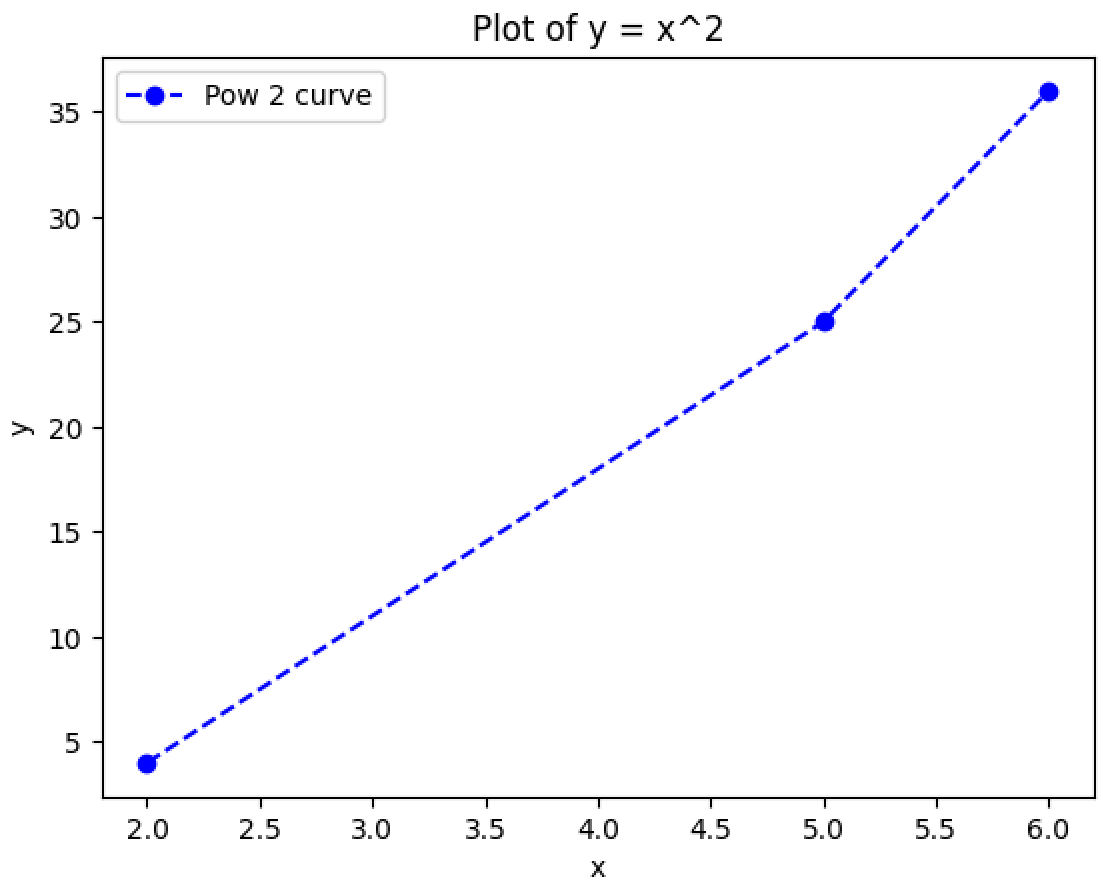


Use format string (faster)

Instead of specifying `marker = 'o'` and `linestyle = '--'`, we can simply use format string `"bo--"`, stands for blue marker `o` and dashed line.

Format of format string is `color` + `marker` + `line type`.

```
plt.plot(x, y, "bo--")
```



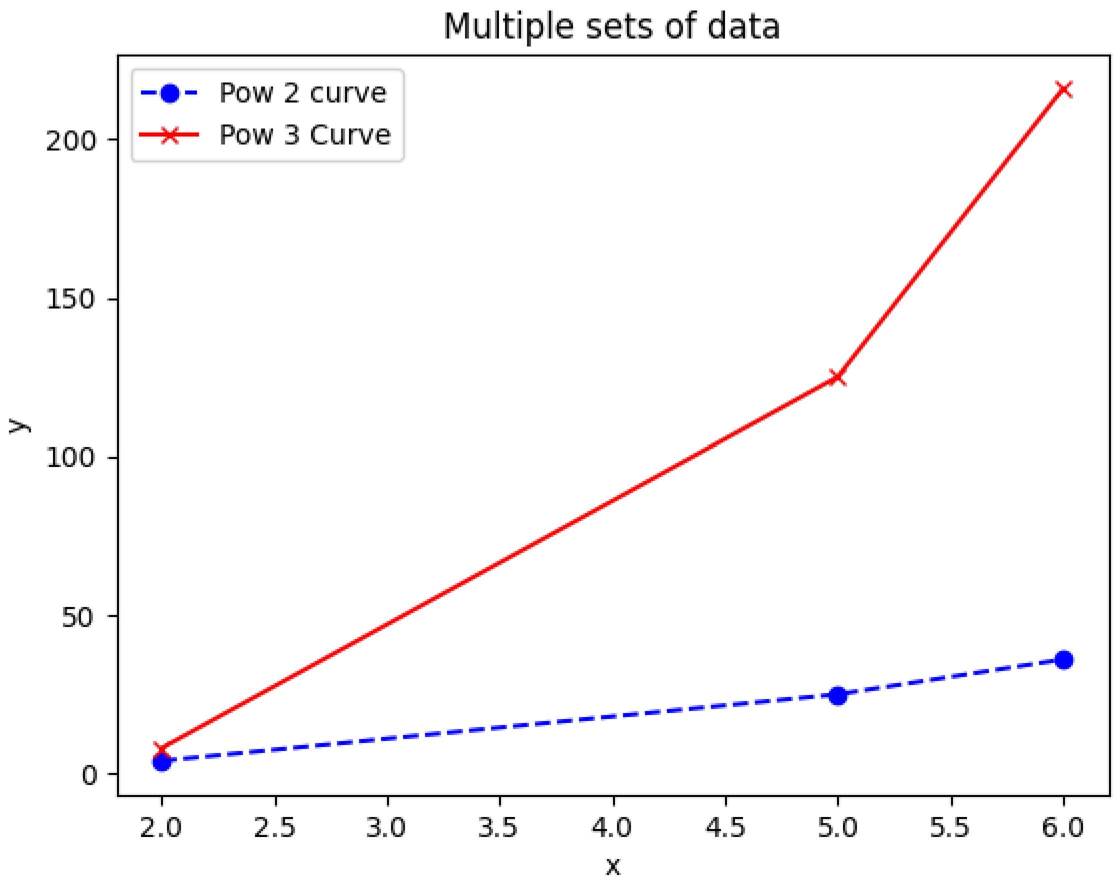
Plot multiple sets of data

To plot multiple sets of data, the most straightforward way is to call `plot()` multiple times.

```
plt.plot(x1, y1)
plt.plot(x2, y2)
```

Example: let's add another set of data where `y = x^3`.

```
# y = x^2
x1 = np.array([2, 5, 6])
y1 = x1 ** 2
# y = x^3
x2 = np.array([2, 5, 6])
y2 = x2 ** 3

# Blue marker 'o' dashed line
plt.plot(x1, y1, "bo--", label="Pow 2 curve")
plt.plot(x2, y2, "rx-", label="Pow 3 Curve")
```

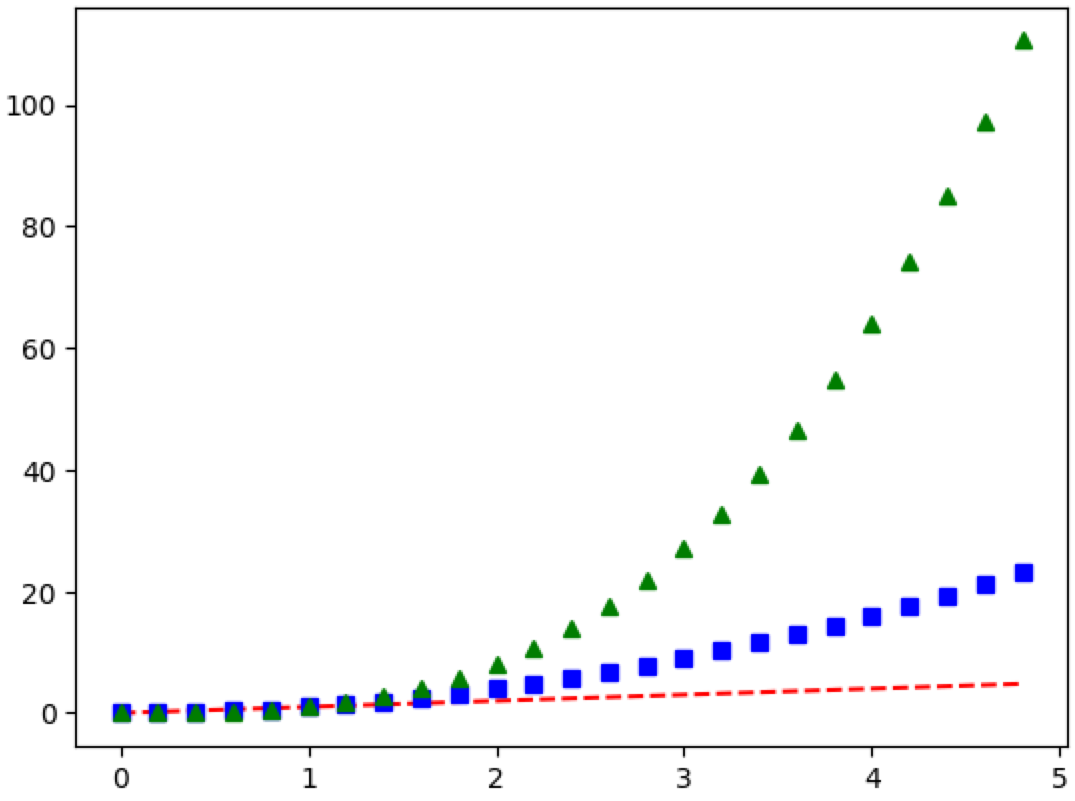


The second way is to specify multiple sets of x and y.

```
plt.plot(x1, y1, marker='o', x2, y2,marker='x')
```

Example:

```
# Chia đoạn từ 0 đến 5 thành các bước 0.2
t = np.arange(0., 5., 0.2)

# Vẽ 3 đường
# 1. Red dashed line: y = x
# 2. Blue color, square marker, no line: y = x^2
# 3. Green color, triangle marker, no line: y = x^3
plt.plot(t, t, 'r--',   # red dashed line
         t, t**2, 'bs', # blue color, sqr marker, no line
         t, t**3, 'g^') # Triangle down is v, up is ^
```



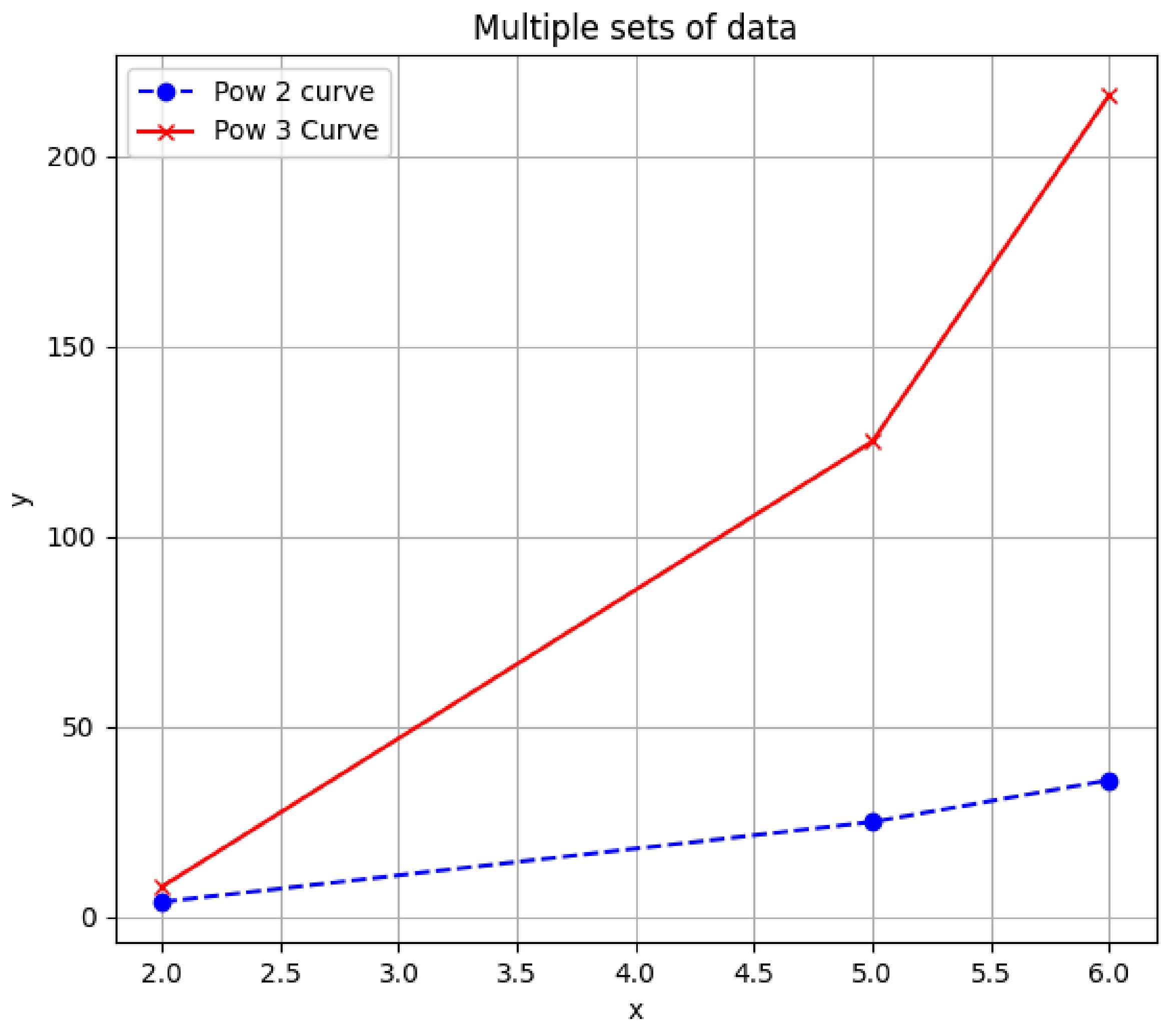
Display as figure and Save as image

Use `plt.figure(figsize=(height, width))` to create a figure with corresponding size. To save the image, use `plt.savefig(file_location)`.

```
plt.figure(figsize=(7, 6))
... # Define the plot
plt.savefig("figure.png") # Remember to put before show()
plt.show()
```

> Remember to put `savefig()` before `show()` .

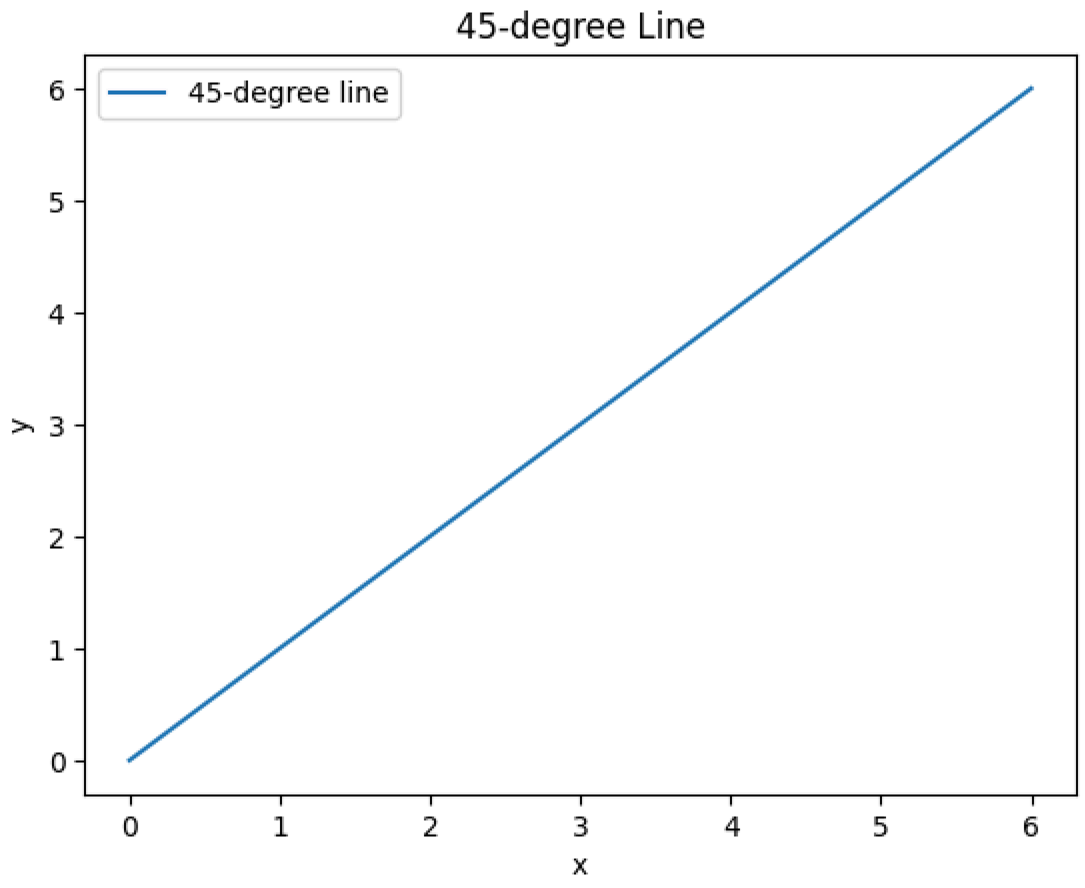
Below is the saved image.



Draw a line with defined angle

For example, with angle = 45 degree, the code is.

```
# Draw a 45-degree line
# => tan(45) = y / x
# => y = x * tan(45)
# Use math.tan(45)
import math

# Define x and y
x = np.array([0, 1, 2, 3, 4, 5, 6])
y = x * math.tan(math.pi / 4) # tan(pi / 4) = tan(45)

plt.plot(x, y, label = "45-degree line")
plt.title('45-degree Line')
plt.xlabel('x')
plt.ylabel('y')
plt.legend()
plt.show()
```



4. Bar Chart (`plt.bar()`)

Used for comparing categories
For comparing numeric values of several groups

Purpose:

Common in economics for:

- Comparing GDP by country
- Comparing production by sector
- Comparing firm revenues

Function:

```
plt.bar(x, height, color=None)
```

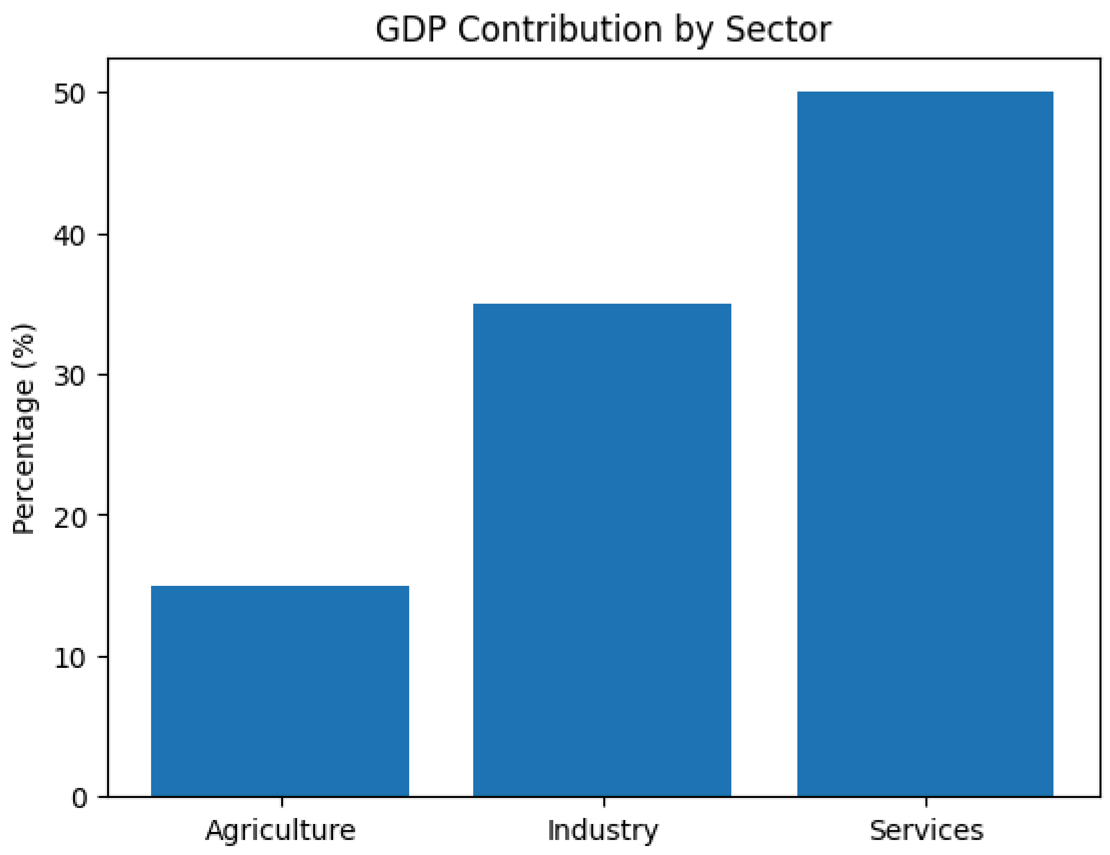
Parameters:

Parameter	Meaning
`x`	Categories (strings or numbers)
`height`	Values
`color`	Bar color

Example:

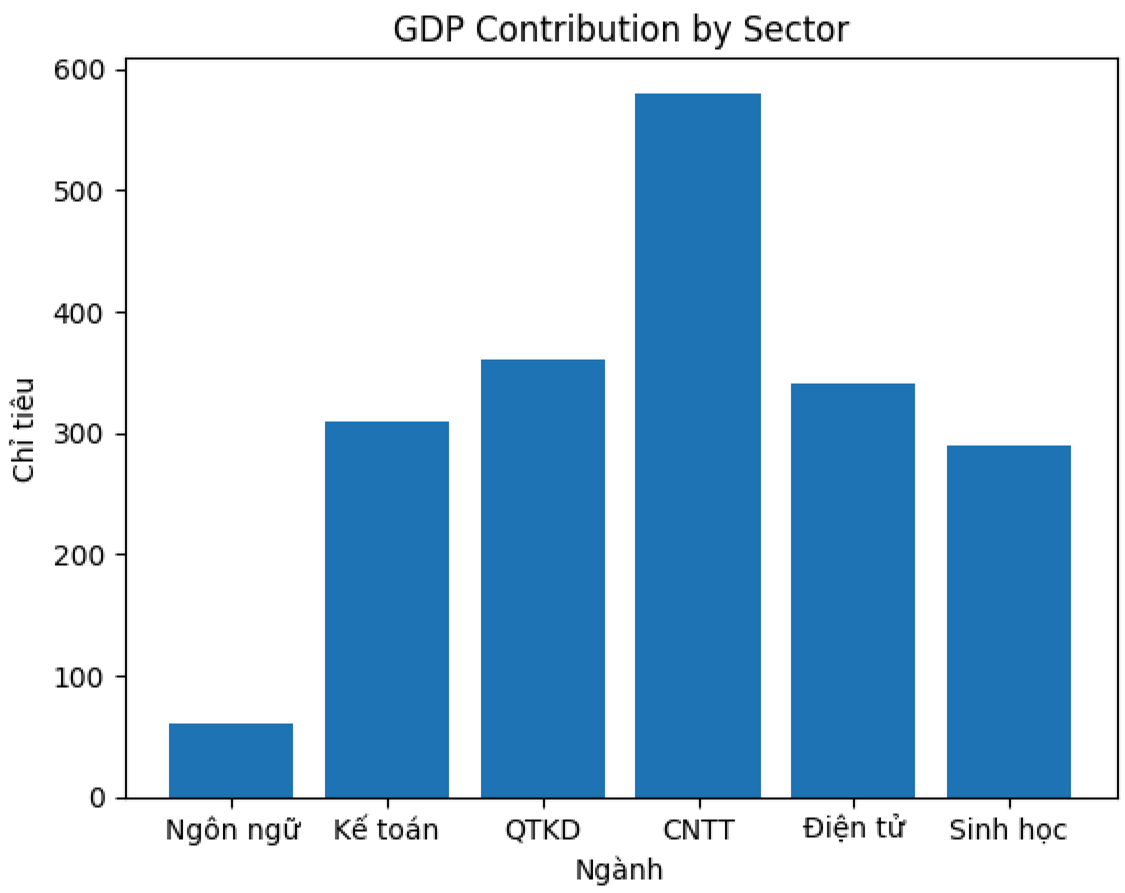
```
categories = ["Agriculture", "Industry", "Services"]
values = [15, 35, 50]

plt.bar(categories, values)
plt.title("GDP Contribution by Sector")
plt.ylabel("Percentage (%)")
plt.show()
```

Output:



Instead of using 2 arrays, we can use **dictionary**. For example.

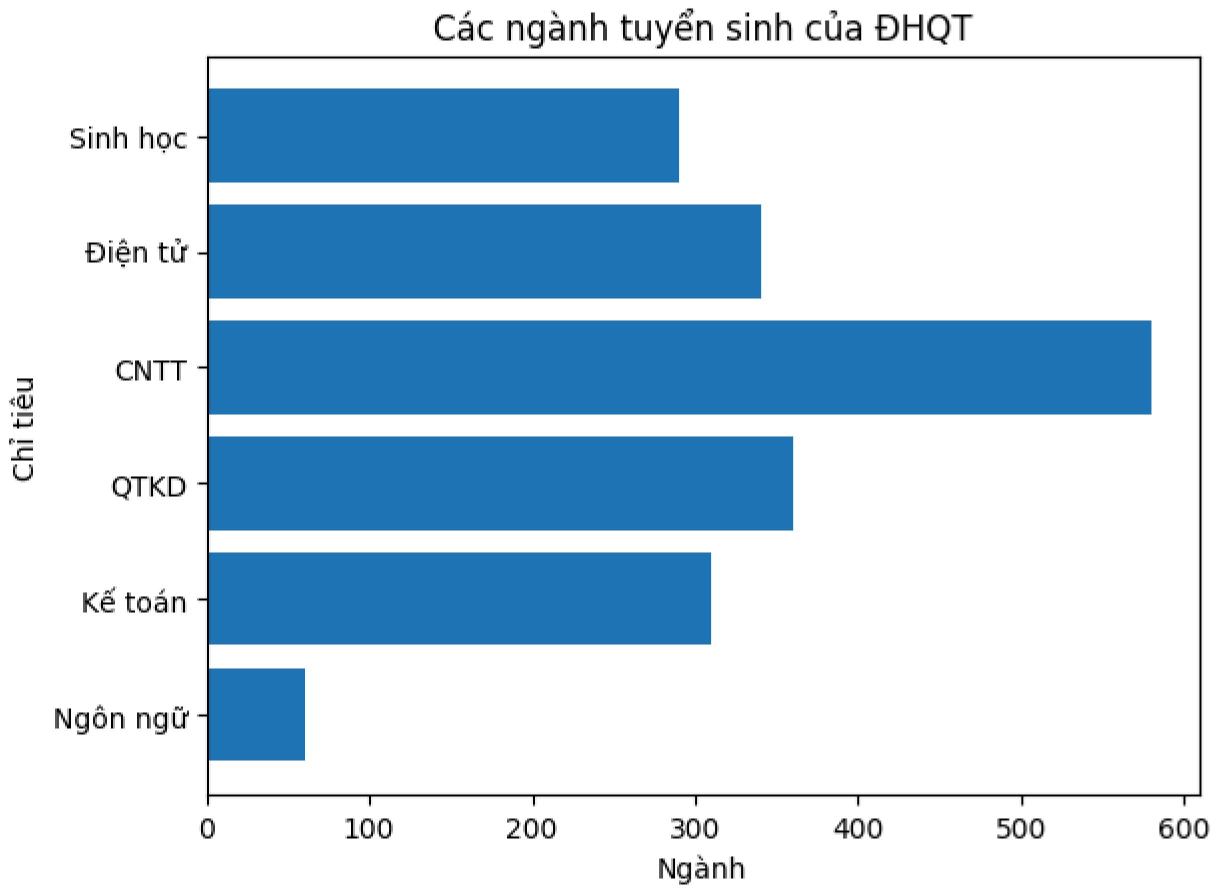
```
dict = {
  'Ngôn ngữ': 60,
  'Kế toán': 310,
  'QTKD': 360,
  'CNTT': 580,
  'Điện tử': 340,
  'Sinh học': 290
}
# dict.keys() --> 'Ngôn ngữ', 'Kế toán', ...
# dict.values() --> 60, 310, ...

plt.bar(dict.keys(), dict.values())
plt.title("Các ngành tuyển sinh ĐHQT")
plt.xlabel("Ngành")
plt.ylabel("Chỉ tiêu")
plt.show()
```



Horizontal bar char (`plt.barh()`)

Use `plt.barh()` to plot horizontal bar chart.

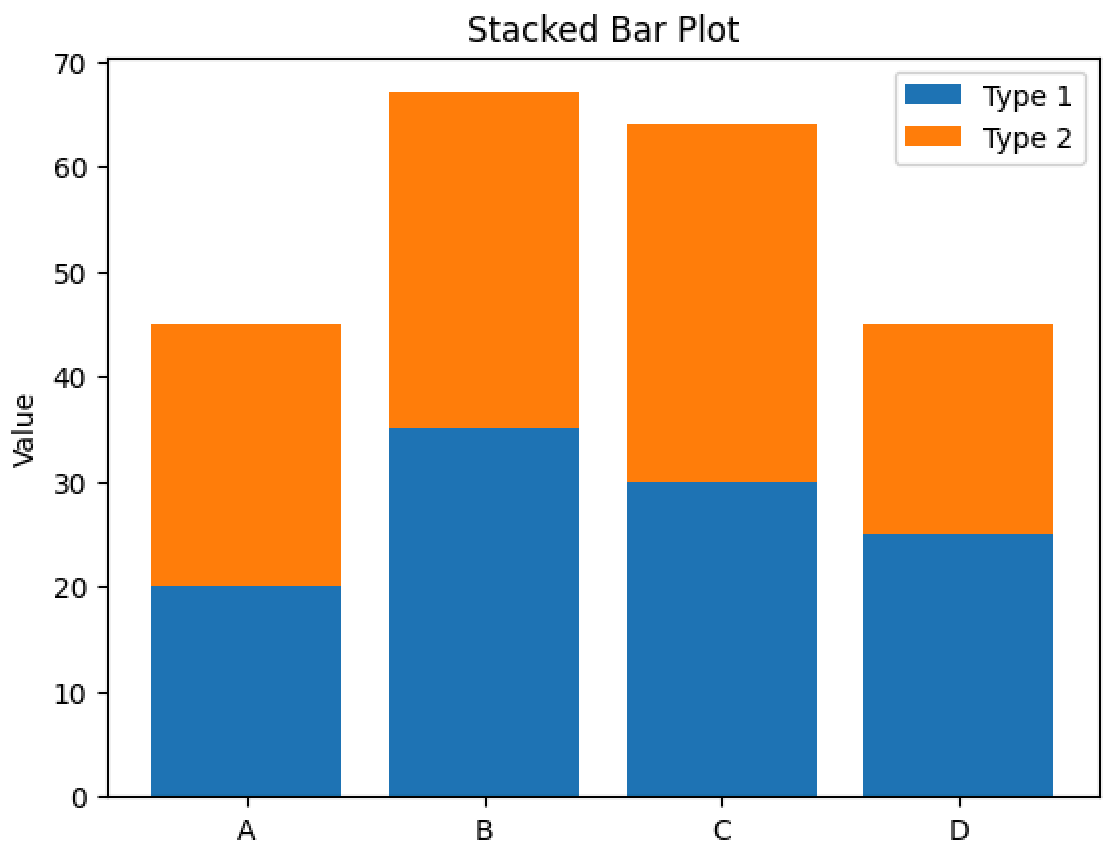
```
dict = {
  'Ngôn ngữ': 60,
  'Kế toán': 310,
  'QTKD': 360,
  'CNTT': 580,
  'Điện tử': 340,
  'Sinh học': 290
}

plt.barh(dict.keys(), dict.values(), align='center') # Horizontal bar
plt.title("Các ngành tuyển sinh của ĐHQT")
plt.xlabel("Ngành")
plt.ylabel("Chỉ tiêu")
plt.show()
```



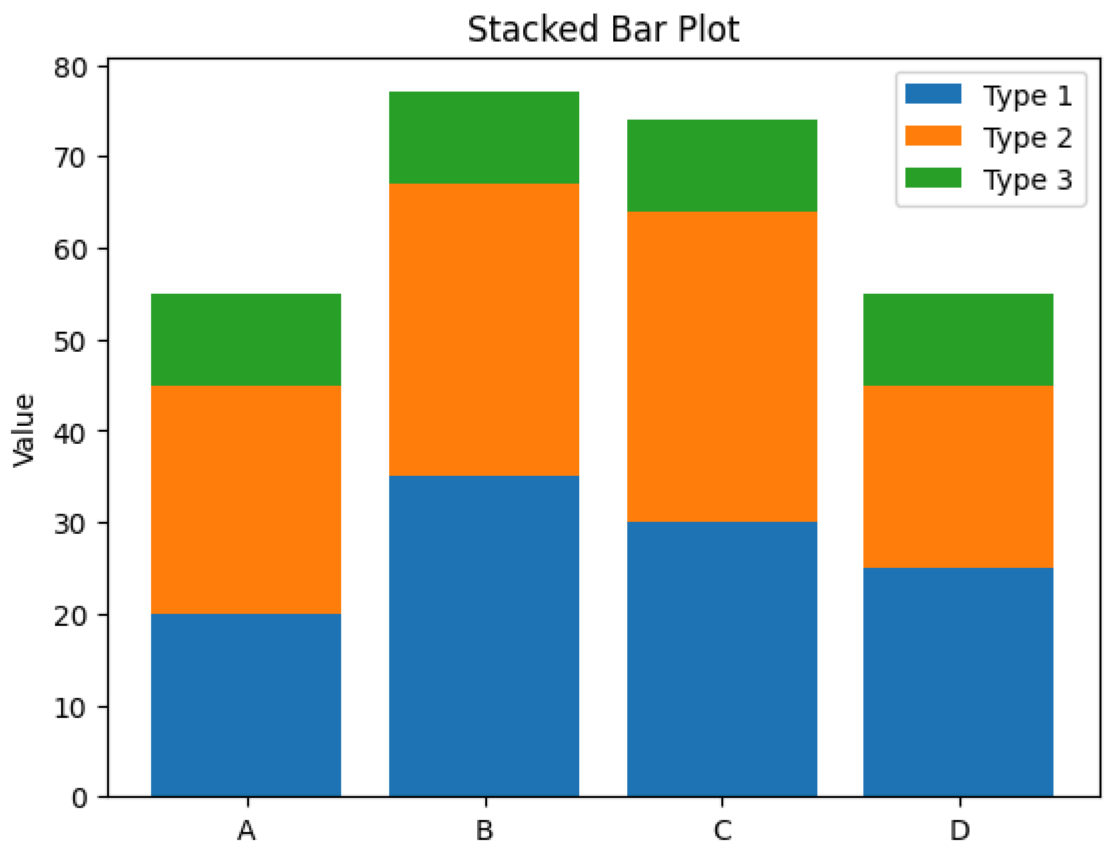
Stacked Bar Chart

Use `bottom` argument in `plt.bar()`. For example.

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

categories = ['A', 'B', 'C', 'D']
part1 = [20, 35, 30, 25]
part2 = [25, 32, 34, 20]

x = np.arange(len(categories)) # x = [0,1,2,3]

plt.bar(x, part1, label='Type 1')
# Define the bottom as part1, so that
# part2 = part1 + part2 values. (part1 = offset)
plt.bar(x, part2, bottom=part1, label='Type 2')

plt.xticks(x, categories) # assign labels to x axis
plt.ylabel('Value')
plt.title('Stacked Bar Plot')
plt.legend()
plt.show()
```



```python
categories = ['A', 'B', 'C', 'D']

# Should define it as numpy array, convenient for
# array/matrix operations
part1 = np.array([20, 35, 30, 25])
part2 = np.array([25, 32, 34, 20])
part3 = np.array([10, 10, 10, 10])

x = np.arange(len(categories)) # x = [0,1,2,3]

plt.bar(x, part1, label='Type 1')
# Define the bottom as part1, so that
# bottom_part2 = part1 + (part2 values).
plt.bar(x, part2, bottom = part1, label='Type 2')
plt.bar(x, part3, bottom = part1 + part2, label='Type 3')

plt.xticks(x, categories) # assign labels to x axis
plt.ylabel('Value')
plt.title('Stacked Bar Plot')
plt.legend()
plt.show()
```

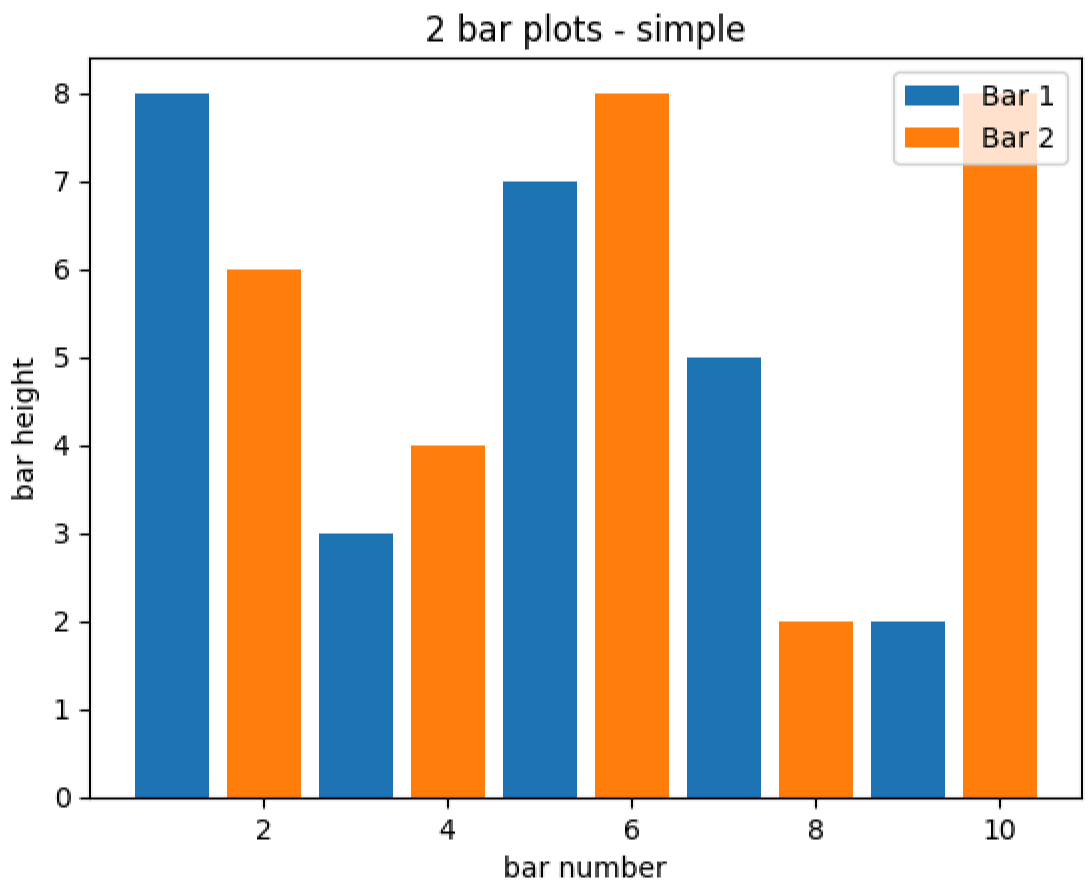


2 bar plots

Simple method

Use 2 dictionaries (4 arrays) to plot it. Fill each dictionary with its own data.

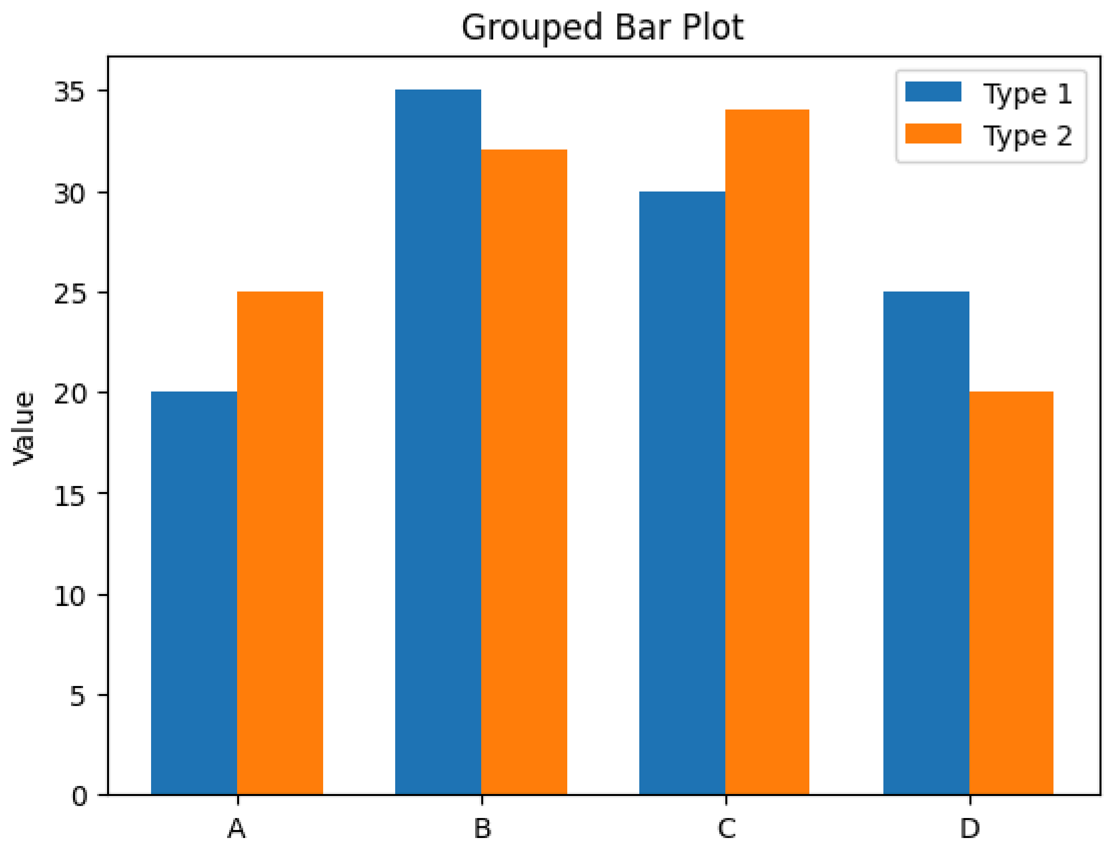
```python
x1 = np.array([1, 3, 5, 7, 9])
y1 = np.array([8, 3, 7, 5, 2])

x2 = np.array([2, 4, 6, 8, 10])
y2 = np.array([6, 4, 8, 2, 8])

# Fill bar plot 1
plt.bar(x1, y1, label="Bar 1")
# Fill bar plot 2
plt.bar(x2, y2, label="Bar 2")
plt.legend()
plt.xlabel('bar number')
plt.ylabel('bar height')
plt.title('2 bar plots - simple')
plt.show()

# If want x axis to appear from 1 to 10, add this command
# full_x = np.concatenate([x1, x2])
# plt.xticks(full_x)
```



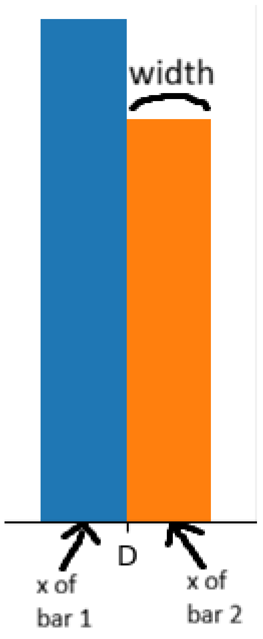
More beautiful method

The above method does not display 2 categories sticking together. If we want no space between 2 categories bar chart, define their locations. Explaination is after the code.

```
categories = ['A', 'B', 'C', 'D']
data1 = [20, 35, 30, 25]
data2 = [25, 32, 34, 20]

x = np.arange(len(categories))
width = 0.35

# Set the position for bar plot 1
plt.bar(x - width/2, data1, width, label='Type 1')
# Set the position for bar plot 2
plt.bar(x + width/2, data2, width, label='Type 2')

plt.xticks(x, categories)
plt.ylabel('Value')
plt.title('Grouped Bar Plot')
plt.legend()
plt.show()
```



The explaination can be visualized through this image.



---

5. Histogram (`plt.hist`)

Displays a distribution of numerical data by grouping it into "bins" or intervals, then showing the frequency of data points within each bin as a bar.

Purpose:

Used to visualize:

- Income distribution
- Returns distribution
- Price variation
- Residuals in regression

Function:

```
plt.hist(data, bins=10, density=False)
```

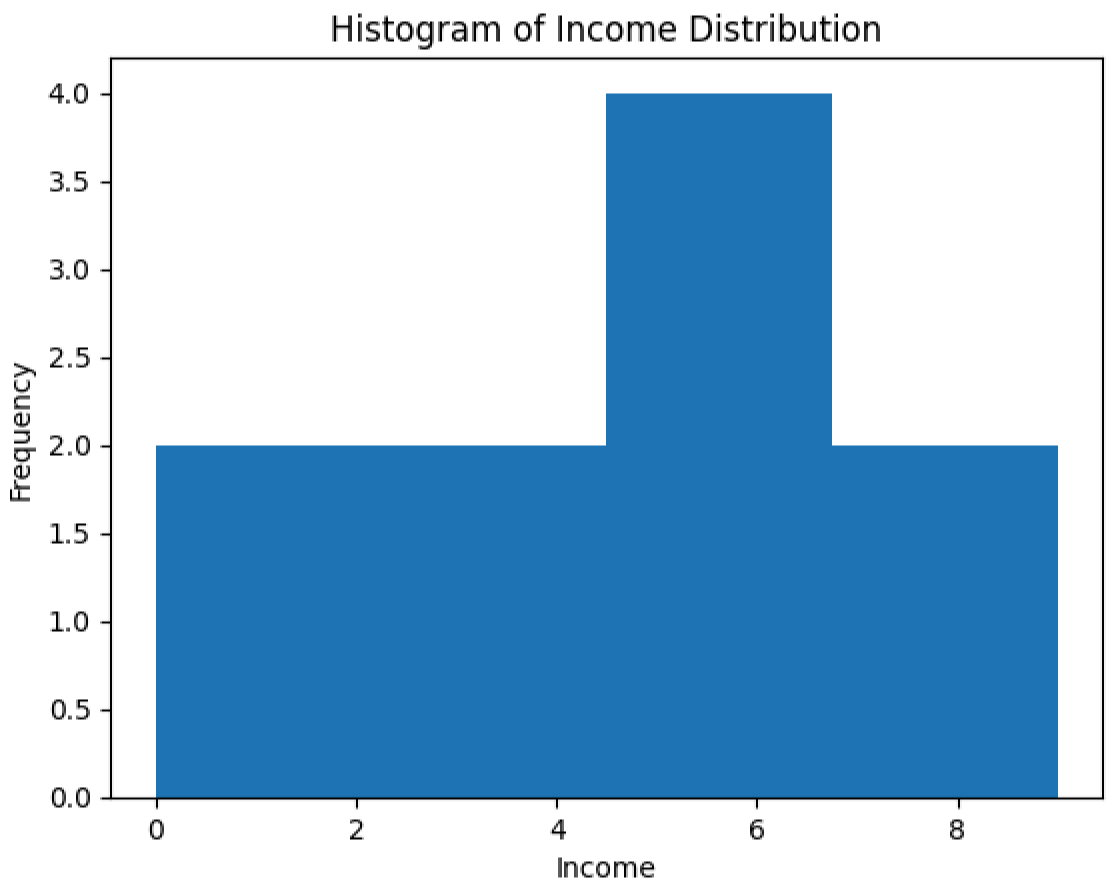
Parameters:

Parameter	Meaning
`data`	Numerical data (array or sequence of (n,) arrays)
`bins`	Number of bars. If *bins* is integer, it defines # of equal-width bins in the range. If *bins* is sequence, it defines bin edges. Example below.
`density`	Normalize to probability

Example:

```
import numpy as np

data = np.random.randint(0, 10, size = 10)
# data = [5, 6, 7, 9, 0, 5, 4, 5, 4, 0]

plt.hist(data, bins=4)
plt.title("Histogram of Income Distribution")
plt.xlabel("Income")
plt.ylabel("Frequency")
plt.show()
```

Output:



6. Scatter Plot (`plt.scatter()`)

Used to study relationships between variables.

Purpose:
Very common in economics:

- Income vs consumption
- Education vs wage
- Price vs demand

Function:

```
plt.scatter(x, y, color=None, s=None)
```

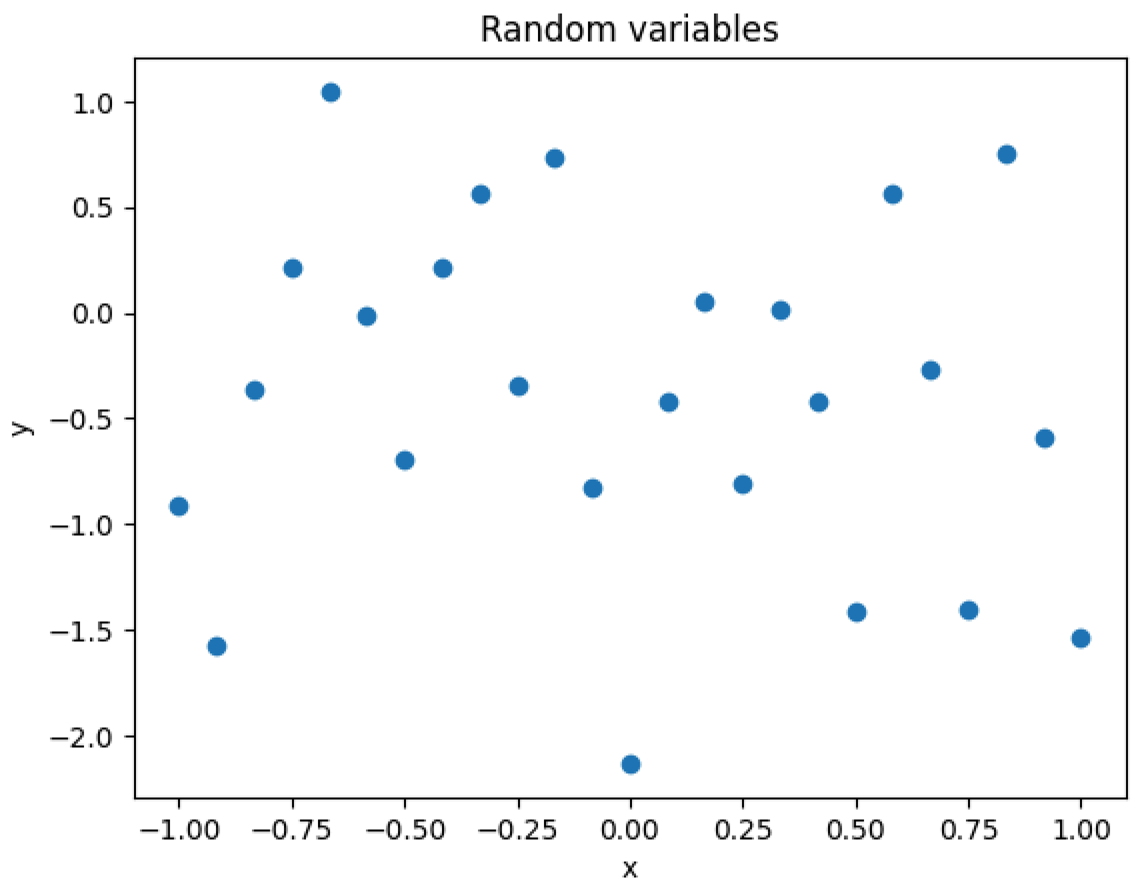
Parameters:

Parameter	Meaning
`x` , `y`	Data points
`color`	Point color
`s`	Point size

Example:

```
x = np.linspace(-1, 1, 25)
y = np.random.randn(25)

plt.scatter(x, y)
plt.title('Random variables')
plt.xlabel('x')
plt.ylabel('y')
```

Output:



---

7. Pie Plot (`plt.pie()`)

---

8. Figure Size (`plt.figure()`)

```
plt.figure(figsize=(8, 5))
```

Value	Meaning
`figsize=(width, height)`	Size in inches

Used to make plots clearer in reports.

---

9. Grid (`plt.grid()`)

```
plt.grid(True)
```

Adds grid lines – **very useful for reading values**.

---

10. Saving Plots (`plt.savefig()`)

```
plt.savefig("output.png", dpi=300)
```

Common in reports and assignments.

---

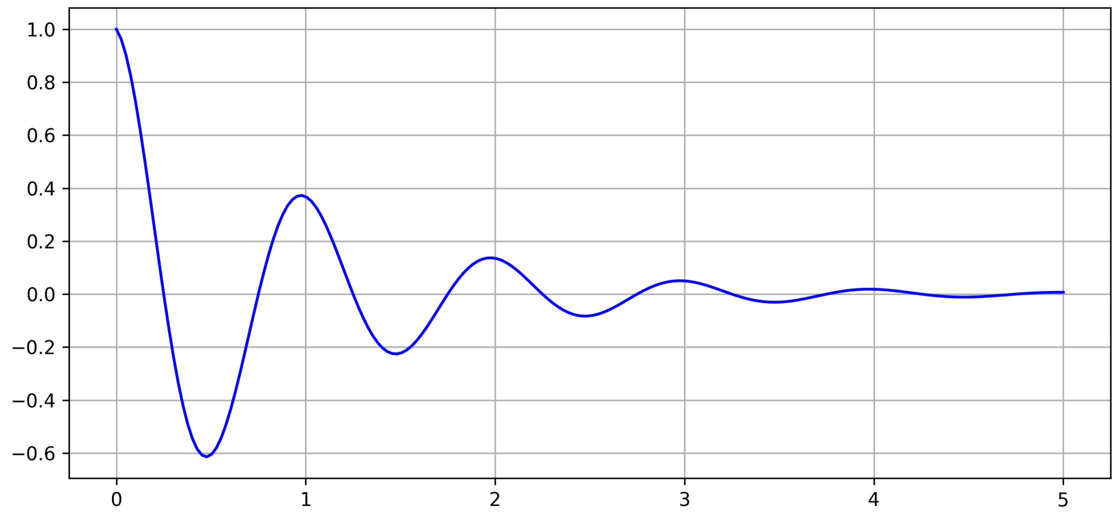
11. Subplots (`plt.subplot()`) – Advanced

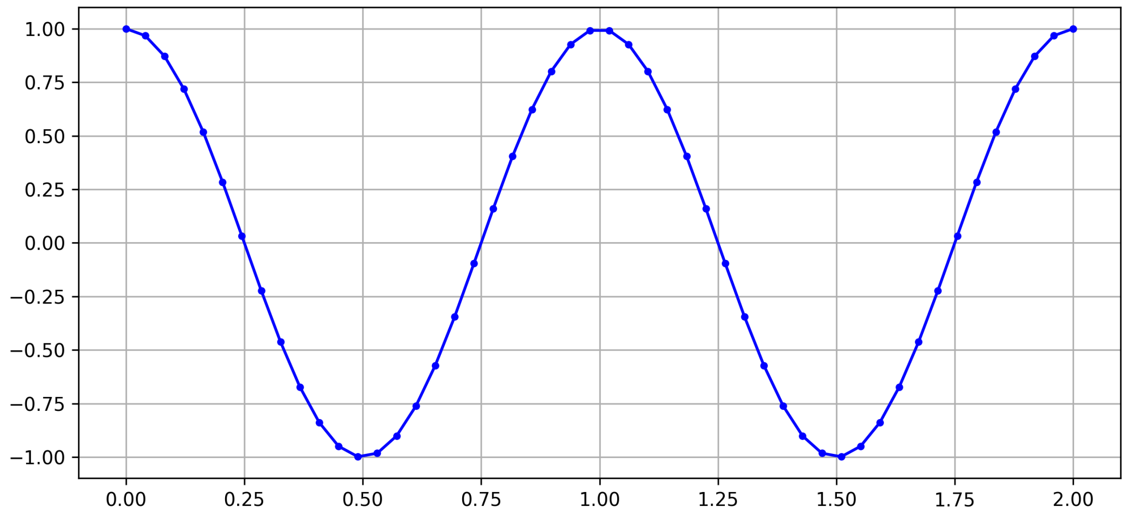
Purpose:

Show multiple plots in one figure.

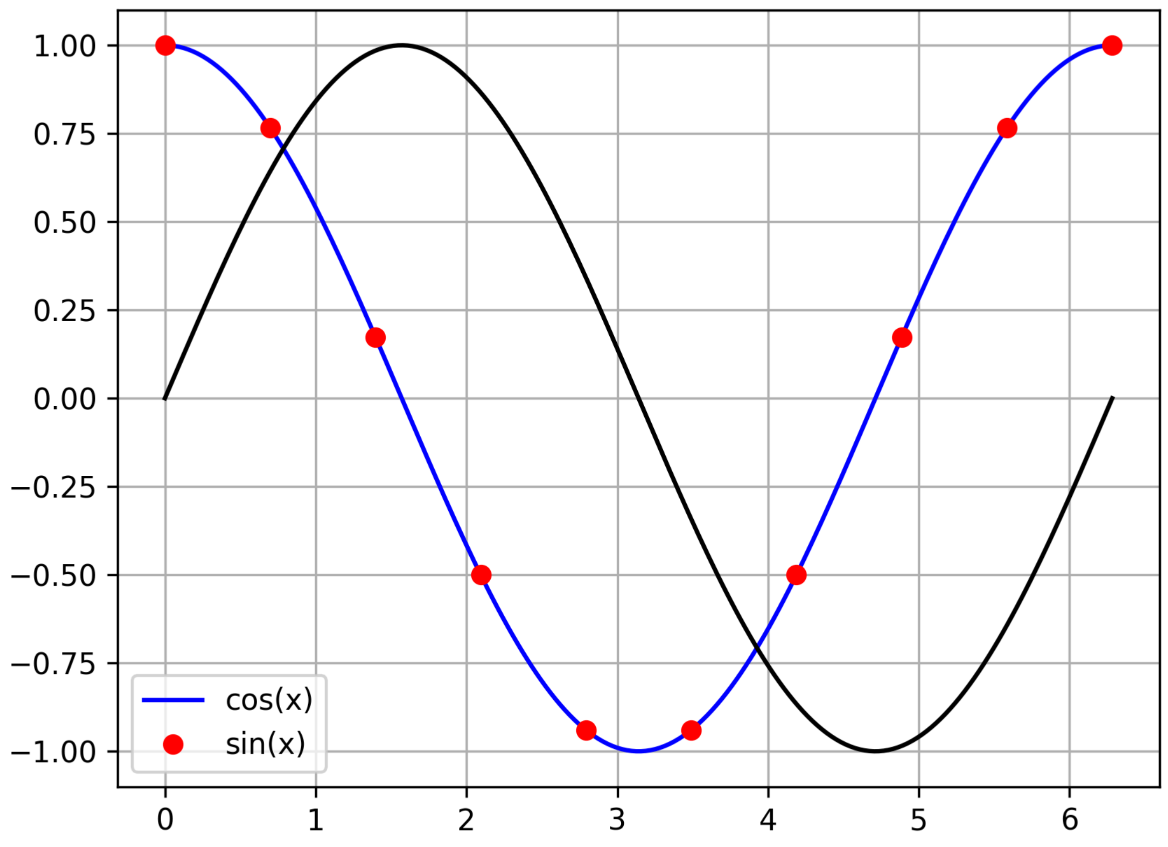
```
plt.subplot(1, 2, 1)  # rows, columns, index
plt.plot(x, y)

plt.subplot(1, 2, 2)
plt.hist(data)

plt.show()
```

```python
from numpy import *
from pandas import *
from matplotlib.pyplot import *

x1 = linspace(0.0, 5.0, 200)
x2 = linspace(0.0, 2.0)

y1 = cos(2 * pi * x1) * exp(-x1)
y2 = cos(2 * pi * x2)

figure(figsize=(10, 10))

subplot(2, 1, 1)
plot(x1, y1, color = 'blue')
grid(True)

subplot(2, 1, 2)
plot(x2, y2, '.-',color = 'blue')
grid(True)
savefig("2cos.png", dpi=300)
show()
```


1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
0
1
2
3
4
5

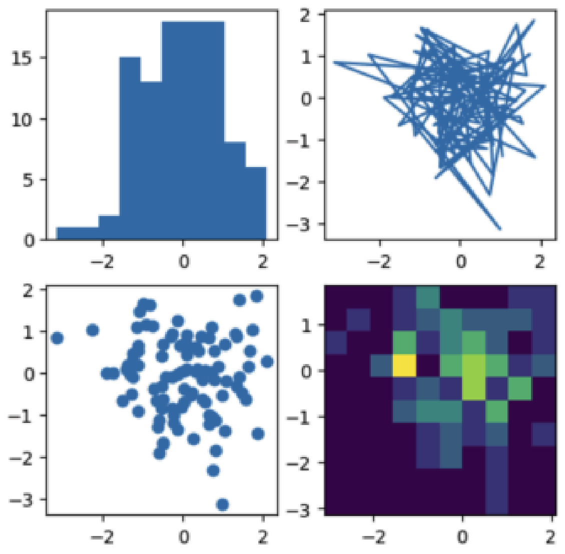

1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00

```python
from numpy import *
from pandas import *
from matplotlib.pyplot import *

x = linspace(0.0, 2 * pi, 200)

y1 = cos(x)
y2 = sin(x)

# highlight_x = pi
highlight_x = linspace(0, 2 * pi, 10)
highlight_y1 = cos(highlight_x)

plot(x, y1, color = 'blue')
# legend("cos(x)")
plot(highlight_x, highlight_y1,'o', color = "red")
plot(x, y2 ,color = 'black')
# legend("sin(x)")
grid(True)
legend(["cos(x)","sin(x)"])
savefig("1cos.png", dpi=300)
show()
```



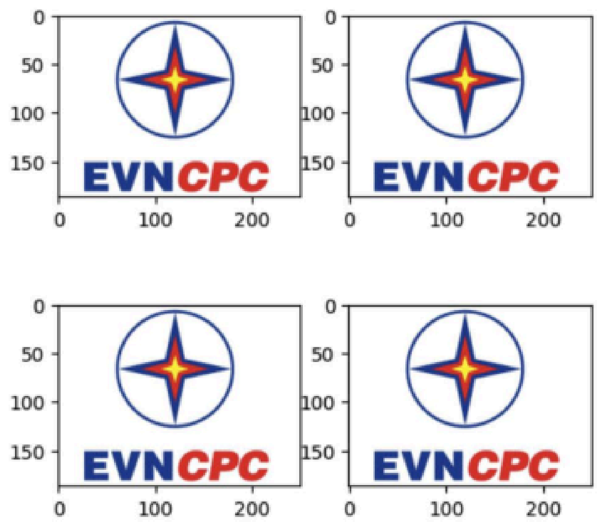
Sub Plot

```
import matplotlib.pyplot as plt
import numpy as np
np.random.seed(19680801)
data = np.random.randn(2, 100)
fig, axs = plt.subplots(2, 2, figsize=(5, 5))
axs[0, 0].hist(data[0])
axs[1, 0].scatter(data[0], data[1])
axs[0, 1].plot(data[0], data[1])
axs[1, 1].hist2d(data[0], data[1])
plt.show()
```



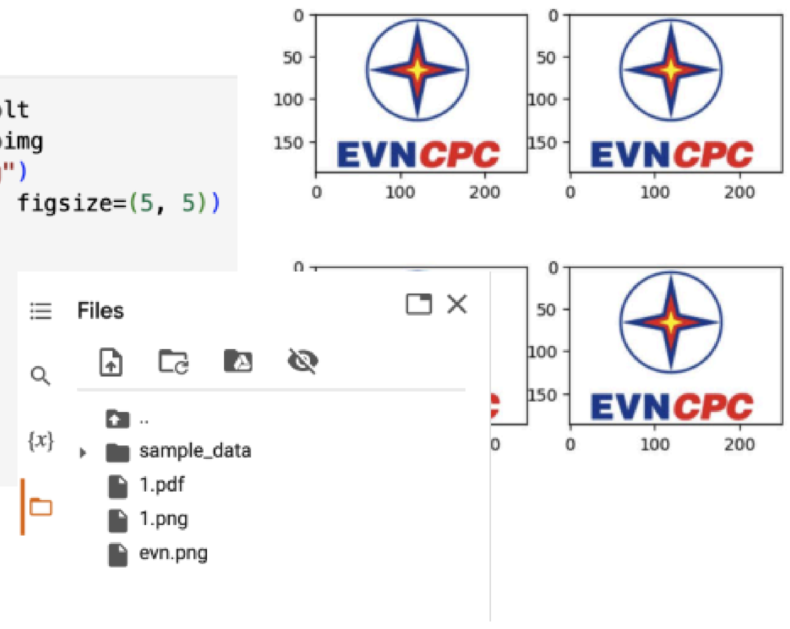
Load existing figure

```python
import matplotlib.pyplot as plt
import matplotlib.image as mpimg
image = mpimg.imread("evn.png")
fig, axs = plt.subplots(2, 2, figsize=(5, 5))
axs[0, 0].imshow(image)
axs[1, 0].imshow(image)
axs[0, 1].imshow(image)
axs[1, 1].imshow(image)
plt.show()
```



Save to file

```python
import matplotlib.pyplot as plt
import matplotlib.image as mpimg
image = mpimg.imread("evn.png")
fig, axs = plt.subplots(2, 2, figsize=(5, 5))
axs[0, 0].imshow(image)
axs[1, 0].imshow(image)
axs[0, 1].imshow(image)
axs[1, 1].imshow(image)
plt.show()
plt.savefig('1.png')
plt.savefig('1.pdf')
```



12. Common Exam Mistakes

❌ Forgetting `plt.show()`

✗ Mixing x and y lengths
✗ Forgetting labels and titles
✗ Using bar chart instead of histogram