

ENGG1003 - Lab 2

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1 Library Basics

This lab will be your first official introduction to using Python *libraries*.

A library is a collection of *functions* (blocks of code referenced by name with specific input, functionality, and output) which perform tasks beyond those “built in” to the Python language.

For example, Python has no built in way of calculating square roots so this mathematical operation is implemented in the `sqrt()` function from the `math` or `numpy` libraries.

Libraries can also contain data in addition to functions. For example, the `math` library (used in the task below) contains the numerical constant π , accessed by using the text `pi`.

Task 1: Math Library Example

Read through Section 1.3 of the textbook (https://link.springer.com/chapter/10.1007/978-3-030-16877-3_1#Sec9).

Be sure to observe the (intentional!) error which results from running the first code example

The full documentation for all `math` library functions can be read here: <https://docs.python.org/3/library/math.html>

2 Importing Library Functions

Python allows for several different ways to *import* libraries, each with their own *syntax* and behaviour.

Task 2: Importing Libraries

Read through Section 1.4 of the textbook https://link.springer.com/chapter/10.1007/978-3-030-16877-3_1#Sec10

Note the difference between:

- `from library import things`
- `from library import *`
- `import library`
- `import library as name`

Section 1.4.5 lists the libraries used by the textbook. Some of them (like `math`) are installed by default while others need to be explicitly installed.

3 Installing Libraries

Normally you would only install the libraries needed for a particular project. It is also best practice to limit the installation of a library to a *virtual environment*. The reasons can be complex, but you should be aware that libraries are often under constant development and their behaviour can change as updates are released. Containing each Python project inside a virtual environment means that each project can use different versions of each library. This is done so that code written in the past will continue to work as new updates are released because that project's virtual environment only contains libraries known to work with that code.

Task 3: Installing Libraries

Install the `numpy` and `matplotlib` libraries in your PyCharm project.

To do this, click on the “Terminal” tab (to the left of the “Python Console” tab) and execute the following commands:

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

Test that the installation was successful by running `import numpy` and `import matplotlib` in the Python console.

4 An Introduction to Plotting and Vectorisation

This section requires `numpy` and `matplotlib` so if you skipped the previous Task please go back and finish it.

Plotting requires a new programming concept: the *array* (also known as a *vector* or, in Python a *list*). So far a single variable has been a single value (eg: `g = 9.8`). An array is an ordered collection of numbers all referred to by the same variable name.

In the task below you will see a line of code which reads:

```
t = np.linspace(0, 1, 1001)
```

This line of code uses the `linspace` library function to create an array of 1001 numbers linearly spaced between 0, and 1.¹

Task 4: Your First Array

Run the following code in the Python Console and observe the resulting array of values:

```
import numpy as np
x = np.linspace(0,10,11)
print(x)
```

Note how the numbers 0 to 10 are printed. All of these values are stored as a “group” inside the variable `x`. The trailing decimal points indicate that the values are *floating point* numbers - more on these later, but a `float datatype` is required to store numbers with both integer and fractional components.

In Python (and most programming languages) you can only plot *numbers*. This is a subtle but crucial point: Python (specifically the `matplotlib` library) doesn't understand how to draw an “equation” or “formula”. It is only able to join lines between an ordered set of points on a 2D plane.

¹Complete `linspace()` documentation is here: <https://numpy.org/doc/stable/reference/generated/numpy.linspace.html>

To plot the graph of an equation you must first write other Python code which generates a set of points on that graph then pass the resulting arrays to `matplotlib`.

To do this “simply” (in few lines of code) a new idea is required: *vectorisation*. Vectorisation is a large topic, but for now know that using an array in a mathematical expression repeats the calculation for *every* value in the array.

Note the output of the previous task: the variable `x` contained 11 values. The next example will demonstrate *vectorising* some arithmetic using that result.

Task 5: Vectorisation Example

Building on the code in the previous task, copy the code below into a script and run it. Observe that the result of the $y = 2 * x$ expression is also an array. All 11 values in `x` have been multiplied by 2 and the results packed into the `y` variable.

```
import numpy as np
x = np.linspace(0,10,11)
print(x)
y = 2*x
print(y)
```

With those fundamental principles explored, now is a good time to complete reading and executing textbook Section 1.5.

Task 6: Section 1.5

Read through and execute all code in textbook Sections 1.5 and 1.6.

Link: https://link.springer.com/chapter/10.1007/978-3-030-16877-3_1#Sec16

5 Further Exercises

Task 7: Plotting Polynomials

With what you have learned so far, write a Python script which initialises three variables: a , b , and c , and plots the resulting parabola from the equation:

$$y = ax^2 + bx + c \quad (1)$$

Experiment with the range of x values used so that the graph produced for $a = 2$, $b = 5$, and $c = -2$ clearly shows both roots (x-axis crossings). Estimate their values from the plot and compare your numbers to the exact values of:

$$x = -\frac{5}{4} - \frac{\sqrt{41}}{4} = -2.8508$$
$$x = -\frac{5}{4} + \frac{\sqrt{41}}{4} = 0.35078$$

Task 8: Plotting Mathematical Functions

The `numpy` library includes a vast array of mathematical functions from trigonometry to logarithms. Write a Python script which plots $\sin(x)$, $\cos(x)$, and $\tan(x)$ on the same graph from 0 to 4π .

You will encounter a problem: $\tan(x)$ approaches $\pm\infty$ and, by default, totally obscures $\sin()$ and $\cos()$!

To fix this, read about the `ylim()` library function (from `matplotlib`) and restrict the y-axis to the range $[-1.5, 1.5]$. The documentation is here: <https://stackoverflow.com/questions/10127631/how-to-set-axis-range-xlim-ylim-in-matplotlib/>