

# Lecture I - Introduction

## Programming with Python

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### About this Course

#### About me

- Field: Optimizing and simulating complex systems
- Languages: of choice: Julia, Python and Rust
- Interest: Modelling, Simulations, Machine Learning
- Teaching: OR, Algorithms, and Programming
- Contact: [vlcek@beyondsimulations.com](mailto:vlcek@beyondsimulations.com)

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#### Tip

I really appreciate active participation and interaction!

### Course Outline

- Part I: Introduction to Programming with Python
- Part II: Data Science Tools with Python
- Part III: Programming Projects

### Participation

- Prerequisite for course Management Science (Prof. Goel)
- Try actively participating in this course
- You will find it much (!) easier to follow Prof. Goel
- Materials will be provided in the KLU portal
- Slides are hosted at [beyondsimulations.github.io/Introduction-to-Python](https://beyondsimulations.github.io/Introduction-to-Python)

### Teaching

- Lecture: Presentation of tools and concepts, based on small examples and code snippets
- Tutorial: Hands-on examples to be solved in groups
- Difficulty: Difficult at first, but gradually easier

### Passing the Course

- Pass/fail course
- 75% attendance required for passing the course

- 2 assignments and 1 little project
- You will be given programming exercises to solve
- You can group up (3 students) and work together
- Each student group submits one solution

## Solution

- Provide a code solution to the problem (.py files)
- Code files need to be executable
- Detailed explanations of your code should be provided
- Use comments or docstrings in your code
- Provide a general (verbal) introduction to each problem

...

### Tip

I'd encourage you to start and submit your solution early

## Difficulty of the Course

- We'll cover the basics of programming (in Python) at first
- This is similar to learning a new foreign language
- First, you have to get used to the language and learn words
- Later, you'll be able to apply it and see results
- Similar to learning a language: Practice, practice, practice!

## What to expect

- Some investment in the beginning to see the return later
- You can ask questions and get support anytime
- After completion, you will be able to read code
- and write your own program using Python
- That's quite something!

## Goals of the Course

- Essential concepts and tools of modern programming
- Automated solutions for recurrent tasks
- Algorithm-based solutions of complex problems
- Usage of AI in a specific context

## Python as Language

- Origins: Conceived in late 1980s as a teaching and scripting language
- Simple Syntax: Python's syntax is straightforward and easy to learn
- Versatility: Used in web development, data analysis, artificial intelligence, and more
- Community Support: A large community of users and extensive documentation

## Help from AI

- You are allowed to use AI (GitHub Copilot, ChatGPT, LLama3 ...)

- These new tools are really powerful for learning Python!
- They can help you a lot to get started with programming

...

#### Warning

But you should not simply use them to replace your learning.

## Why learn programming?

### Analytics

Photo by Choong Deng Xiang on Unsplash

### Research

Photo by National Cancer Institute on Unsplash

### Visualization

Photo by Clay Banks on Unsplash

### Finance

Photo by Ishant Mishra on Unsplash

### Logistics

Photo by Denys Nevozhai on Unsplash

## How to learn programming

### My Recommendation

1. Be present: Attend the lecture and participate
2. Put in some work: Repeat lecture notes and try to understand the examples yourself
3. Do coding: Run code examples on your own, play around, google, modify, and solve problems on your own

...

#### Tip

Great resources to start are books and small challenges. You can find a list of book recommendations at the end of the lecture. Small challenges to solve can for example be found on [Codewars](#).

## Don't give up!

- Programming is problem solving, don't get frustrated!
- Expect to stretch your comfort zone

## Learning Path

- The learning path can be quite steep!
- First of all help each other!
- Try to find help in lecture materials and books, the Python documentation, and online (e.g. Google, ChatGPT, StackOverflow, ...)
- In case you get frustrated, read the following [helpful blog post about the challenges on medium.com](#)

## Errors

In case you find errors and typos in the lecture notes, please report them in the following form:

<https://tally.so/r/w7oapa>

## Setting up Python

### Install Python

- Sources are the [Python website](#) or [Anaconda](#)
- But I would recommend we start by installing [Thonny](#)
- An open source IDE running on Windows, Linux and Mac
- Built in Python interpreter and package management!

### What is an IDE?

- Integrated Development Environment = application
- It allows you to write, run and debug code scripts
- Thonny is an IDE specifically for Python beginners
- It is easy to use as beginner!
- Other IDEs include for example [PyCharm](#) from JetBrains or [Visual Studio Code](#) from Microsoft

# Thonny

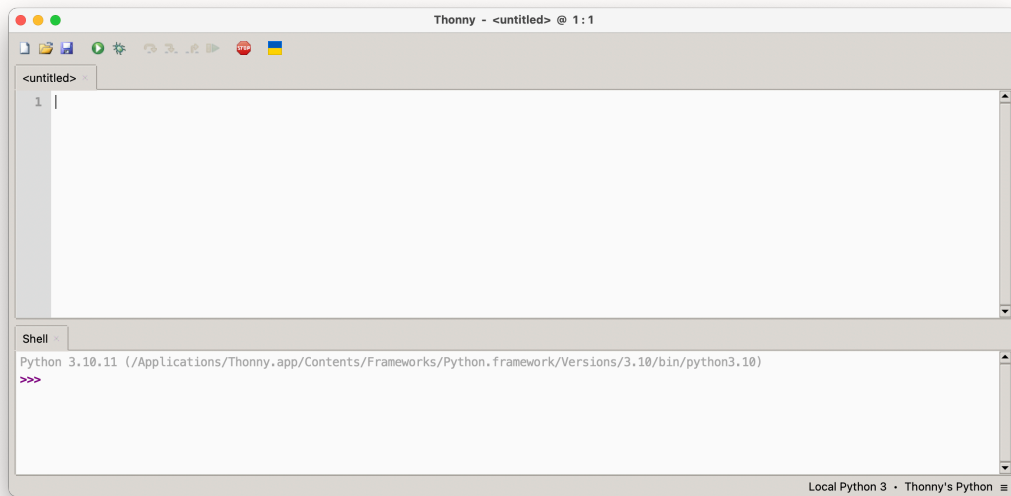


Figure 1: First start of Thonny

## Python on iPads

- Although you can run Python scripts from on your iPad, it is not recommended for the course
- Nonetheless, you could use [Pythonista](#)
- It works locally on your iPad and can run most scripts

...

### Caution

Not all packages available in Python are available in Pythonista, thus you might need a computer to solve certain problems.

## First start of Pythonista

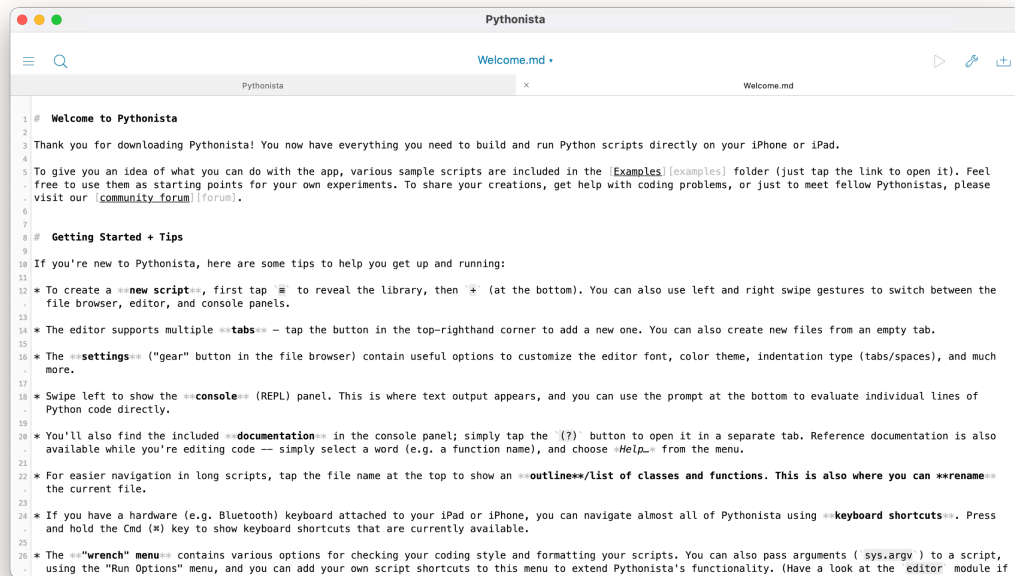


Figure 2: First start of Pythonista

## Your first code

### Hello, World!

Task: Create a directory for the course and create a new file called `hello_world.py` with the following code:

```
# This is a comment in Python
print("Hello, World!")
```

```
Hello, World!
```

...

Run it with the green 'run' button or by pressing F5!

...

#### Note

“Hello world” is a classic example to start with. It is often used as a test to check if your computer is working properly and that you have installed the necessary software.

## Hello, World in a Message

Task: Change the code in your `hello_world.py` file. Assign the string `"Hello, World!"` to a variable called `message` and print the variable.

...

- Use the equals sign (=)
- Variable name goes on the left
- Value to be assigned goes on the right

...

```
# Here we assign the string "Hello, World!" to variable message and print it
message = "Hello, World!"
print(message)
```

```
Hello, World!
```

## Hello, World in Parentheses

We can also mix `"` and `'` in a string, if we are consistent:

```
# This code works
message = 'I shout "Hello, World!"'
print(message)
```

```
I shout "Hello, World!"
```

...

```
# This code does not!
message = 'I shout 'Hello, World!'"
print(message)
```

...

Try it yourself! What does happen, if you try to run it?

## First Errors

SyntaxError: invalid syntax

- The code is not valid Python syntax
- Likely the most common error that you will encounter!
- Happens when you make a mistake, e.g., illegal character, missing a colon, parentheses or quotations
- You can fix this by correcting the code and re-running

- In the lecture you will encounter many more errors!

## Program

### What is a Program?

- Sequence of instructions telling a computer what to do
- Written in a language the computer can understand
- Basic operations in most languages:
  - Input: Data from keyboard, file, network, sensors, etc.
  - Output: Display data, save it, send over network, etc.
  - Processing: Perform calculations, analyze data, make decisions, find patterns, etc.

### Key concepts

- Key concepts in most languages:
  - Variables: Store and manipulate data
  - Conditional execution: Check and execute accordingly
  - Loops: Perform actions repeatedly
  - Functions: Group instructions for reusability

...

#### Note

We will cover these concepts in more detail later in the course.

### How Python executes code

- Python is an interpreted language
- The source code is executed line by line
- The interpreter checks the syntax and executes the code
- This is in contrast to compiled languages, where the code is compiled into machine code before execution

### Hello again, World!

Let's go back to our first program:

```
# Our first program
message = "Hello, World!"
print(message)
```

...

- Comment: In the first line we define a comment with `#`
- Variable: In the second we define a variable `message`
- Function: In the third line we call a function `print`

### Don't worry!

- Already confused? Don't worry about it for now!



- We'll learn more about variables and functions later

## Python's Syntax

### The Zen of Python

- Python's name originally comes from Monty Python
- Style is based on a philosophy called Zen of Python
- Collection of 19 statements with general principles

...

Task: Try this code in Python:

```
# Try this code in Python to see the Zen of Python
import this
```

### Variables

- A variable in Python is a name that points to a value
- Created by using the assignment operator `=`
- Python does not require a declaration of variable types

```
a = 2 # Variable a assigned the value 2
b = "Time" # Variable b assigned the value "Time"
c = print # Variable c assigned the print function
c(b) # Now we can call the print function with c
```

Time

...

But there are certain rules to variable names!

### Variable Naming Conventions

- Must start with a letter or underscore `_`
- Can contain letters, numbers and underscores
- Names are case sensitive, e.g., `a` and `A` are different!
- Cannot be a reserved word, e.g., `for`, `if`, `def`, etc
- Good names are short and meaningful for humans!

...

Question: Which of the following fulfill these conditions?

`a`, `_duration`, `1x`, `time_left`, `1_minute`, `oneWorld`, `xy4792`

### Functions

- Functions are named blocks of code

- Can take arguments `function([arguments])`
- Can return results or `None`

...

```
# Print is such a function
print("Hello, World!") # It takes an argument and prints it to the console
print("Hello", "World!", sep=", ") # It can also take multiple arguments
```

```
Hello, World!
Hello, World!
```

...

### Note

We will cover functions in more detail later in the course.

## Values and Types

### What are Values and Types?

- Value: Fundamental thing that a program manipulates
  - In Python, values are either numbers or strings
- Type: Type of a value
  - Determines what operations can be performed on it
  - `type()` is a function that returns the type of a value
  - Takes one argument and returns its type as string

### Strings

Back to our example of “Hello, World!”

```
# We define the variable message and assign it the value "Hello, World!"
message = "Hello, World!"

# We save its type in another variable called message_type
message_type = type(message)

# We print the value of our new variable
print(f"{message} is a {message_type}")
```

```
Hello, World! is a <class 'str'>
```

...

Result: “Hello, World” is a string - in short ‘str’.

...

But what about the f”?

## Formatted Strings

- f-strings are strings that start with `f`
- They contain expressions, e.g., variables, in braces
- Evaluated at run time and inserted into the string

...

### Note

In older code bases, f strings were not available. Here, interpolation could be done as shown below with `print()` and `.format()`. But this method is less concise and arguably less readable.

...

```
print("{} is a {}".format(message, message_type))
```

```
Hello, World! is a <class 'str'>
```

## Specifying Formatted Strings

- We can further specify their format with `{<to_print>:<width>.<precision>f}`
- `width` can be a number specifying the output width
- `<, ^, >` can be used before the width to align the text
- `precision` can be used to specify the decimals
- `.f` can be used to format floats

```
x = "hello"
print(f"{x:<10} has {len(x):>10.2f} characters.")
```

```
hello      has      5.00 characters.
```

## Expressions

- Produce a value when evaluated
- Can be used as part of larger expressions or statements
- Statements are expressions that don't produce a value
- Examples: arithmetic operations, function calls, variables

```
x = 1 # Statement that assigns the value 3 to x
y = x + 2 # Expression on the right side assigned to a variable y
print(f"Great, the result is {y}")
```

```
Great, the result is 3
```

## A step back: What is a String?

- Remember: “Hello, World” is a string - in short ‘str’
- A string is a sequence of characters enclosed in quotes
- Examples: "Hello", 'World', "123", '1World23'

```
hello = "Hello"
world = 'World!'
print(hello,world,sep=", ") # We can specify the separator with the
argument sep
```

```
Hello, World!
```

...

### Note

Strings are immutable, we can't change characters in them once created.

## String Operations

- But we can also do much more with strings!
- String concatenation, indexing, slicing, length, etc.

```
two_strings = "Hello" + ", " + "World!" # String concatenation
print(two_strings)
```

```
Hello, World!
```

...

```
print(two_strings[0]) # Indexing starts at zero!
```

```
H
```

...

```
print(len(two_strings)) # With len we can find the length of our string
```

```
13
```

...

```
print("--x--"*3) # We can also repeat strings
```

```
--x---x---x---
```

## Booleans

- Booleans represent two values: `True` and `False`
- Internally they are represented as `1` and `0`, respectively
- They are used for logical operations and control flow
- E.g.: `if`, `while`, `for`, `elif`, `else`

...

```
x = True
y = False
print(x)
print(type(y))
```

```
True
<class 'bool'>
```

...

> More on them in our next lecture!

## Integers and Floats

- Integers are whole numbers, e.g.: `1`, `-3`, `0` or `100`
- Floats are decimal numbers, e.g.: `-4.78`, `0.1` or `1.23e2`
- Bit size is not specified (e.g.: 64 bits) in Python!

...

```
x = 1; y = 1.2864e2 # We can separate multiple operations in one line with
semicolons
print(f"{x} is of type {type(x)}, {y} is of type {type(y)}")
```

```
1 is of type <class 'int'>, 128.64 is of type <class 'float'>
```

...

### Warning

The interpreter will automatically convert booleans to integers to floats when necessary, but not the other way around!

## First Functions and Operators

### Arithmetic operators

```

addition = 1 + 2;      print(f"Result: addition is {addition}")
subtraction = 1 - 2;   print(f"Result: subtraction is
{subtraction}")
multiplication = 3 * 4; print(f"Result: multiplication is
{multiplication}")
division = 7 / 4;      print(f"Result: division is {division}")
floor_division = 7 // 4; print(f"Result: floor_division is
{floor_division}")
exponentiation = 9 ** 0.5; print(f"Result: exponentiation is
{exponentiation}")
modulo = 10 % 3;       print(f"Result: modulo is {modulo}")

```

```

Result: addition is 3
Result: subtraction is -1
Result: multiplication is 12
Result: division is 1.75
Result: floor_division is 1
Result: exponentiation is 3.0
Result: modulo is 1

```

## Precedence

- Operators are the same as in most other languages
- Can be combined with each other and variables
- Normal rules of precedence apply

...

```

# Operator precedence works as on paper
combined_operation = 2 + 3 * 4
print(f"2 + 3 * 4 = {combined_operation}")

```

```
2 + 3 * 4 = 14
```

...

```

# Parentheses change precedence as expected
parentheses_operation = (2 + 3) * 4
print(f"(2 + 3) * 4 = {parentheses_operation}")

```

```
(2 + 3) * 4 = 20
```

## The input() Function

- Used to get user input as string from the console
- Syntax: `input([userprompt])`
- Displays optional prompt and waits for user input

...

```
name = input("What's your name? ")
print(f"Hello, {name}!")
```

...

### ! Important

The function always returns the input as string!

## Input in Action

Task: Solve the following task:

```
# TODO: Ask the user for their age and print a compliment
```

...

Solution

```
age = int(input("How old are you? "))
print(f"You look great for {age}!")
```

## Type Conversion

Use type conversion for other data types

1. Integer: `int(input())`
2. Float: `float(input())`
3. Boolean: `bool(input())`
4. String: `str(input())`

...

```
# Converting to Integer
age = int(input("Enter your age: "))
next_year = age + 1
print(f"Next year, you'll be {next_year}")
```

## The round() Function

```
# Hence, we can use the int() function to convert a float into an int
soon_int = 1.789
print(f"{soon_int} converted to {int(soon_int)} of type {type(int(soon_int))}")
```

```
1.789 converted to 1 of type <class 'int'>
```

...

```
# We can also use 'round()' to round a float to an int
soon_int = 1.789
print(f"{soon_int} converted to {round(soon_int)} of type {type(round(soon_int))}")
```

1.789 converted to 2 of type <class 'int'>

...

```
# Or to a float with a certain number of decimals
no_int = 1.789
print(f"{no_int} converted to {round(no_int,1)} of type {type(round(no_int,1))}")
```

1.789 converted to 1.8 of type <class 'float'>

## Questions?

...

### Note

That's it for today's lecture!  
We now have covered the basics on the Python syntax, variables, and data types.

## Literature

### Interesting Books to start

- Downey, A. B. (2024). Think Python: How to think like a computer scientist (Third edition). O'Reilly. [Link to free online version](#)
- Elter, S. (2021). Schrödinger programmiert Python: Das etwas andere Fachbuch (1. Auflage). Rheinwerk Verlag.

...

### Note

Think Python is a great book to start with. It's available online for free [here](#). Schrödinger Programmiert Python is a great alternative for German students, as it is a very playful introduction to programming with lots of examples.

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For more interesting literature to learn more about Python, take a look at the [literature list](#) of this course.