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Python Basics

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Table of Contents

General Introduction

About me

Education

- 2012 – Bachelor of Science UZH in Physics
- 2016 – Master of Science UZH in Computational Science

Work

- 2014 – 2016: Software engineer CERN (remote)
- 2016 – 2021: PDF Tools AG
- 2021 – now: Zurich Instruments

Programming experience

C++, C#, Java, TypeScript, JavaScript, Python

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Learning targets

After this course...

- ... you will have an idea what programming is
- ... you will know how to write a basic computer program
- ... you are able to write a Python program based on a written out problem statement
- ... you know where you can find more information to improve your programming skills

But you only have started to scratch the surface.

Introduction to Programming

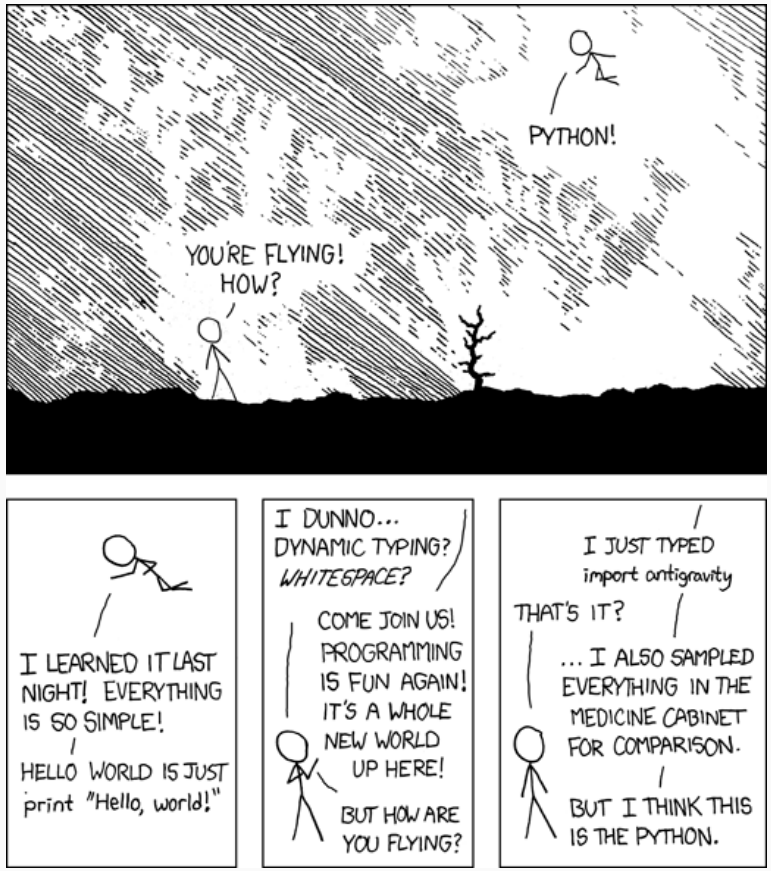
What is a Computer Program

Modular System

- **Input**: Data input from keyboard, files, internet, etc...
- **Output**: Processed data is displayed or saved to a file
- **Algorithms**: The computers cooking recipies
- **Libraries**: Using existing implementations (can do anything of the above)

Why Python?

- High-level programming language
- ”Simple” syntax
- Cross-platform - A script written on a Windows computer also runs on Linux & Mac
- Interpreted => Easy to run
- Many libraries available



Source: https://xkcd.com/353/

Examples: Hello World i

High level languages but not trivial to learn:

Java

```java
public class HelloWorld {
  public static void main(String args[]) {
    System.out.println("Hello World");
  }
}
```

C++

```cpp
#include <iostream>
int main() {
  std::cout << "Hello World\n";
  return 0;
}
```

Examples: Hello World ii

Or even worse:

Machine Language
Example of a low level language

```
.LC0:
  .string "Hello world!"
main:
  push rbp
  mov rbp, rsp
  mov edi, OFFSET FLAT:.LC0
  mov eax, 0
  call printf
  mov eax, 0
  pop rbp
  ret
```

Examples: Hello World iii

Python

```python
print("Hello World")
```

How to Run Python Code

Options to run Python code:

- Directly in the Python prompt (REPL - Read, Eval, Print, Loop)
- Write the code into a file and run python with the file
- Use IDE to run Python code

Development Environment

- Integrated Development Environment (IDE)
- Collection of tools that are commonly used for software development (they make our life easier!)
- Popular IDEs
  - Visual Studio Code - `https://code.visualstudio.com`
  - JetBrains PyCharm - Community Edition available for free `http://jetbrains.com/pycharm/download`
- It takes time to get proficient using an IDE

Fundamental Concepts

Types, Variables, Expressions, Operators, Comments

Data Types, Variables, Expressions, Operators, Comments

Types

- Numbers (Integers, Floats)
  - 2
  - 1000000
  - -2
  - 3.2
  - 1.3333333

Data Types i

Strings

- Strings (Text)
  - 'Hello World'
  - "Hello World"
- 'Single quotes' or "double quotes" can be used to declare them
  - 'Hello World'
  - "Hello World"
  - "5"

Boolean

Binary data type

- True
- False

Data Types ii

None Type

- `None` is a special type (in other languages also sometimes called `null` or `nullptr`). Sometimes it is necessary to indicate that something *is not there* and this can be indicated by using `None`.

Variables i

Variables are used to store information to be referenced and manipulated in a computer program. They also provide a way of labeling data with a descriptive name, so our programs can be understood more clearly by the reader and ourselves. It is helpful to think of variables as containers that hold information. Their sole purpose is to label and store data in memory. This data can then be used throughout your program.

- Variables hold values
- Similar to mathematics
  - x = 2
  - y = x + 2
- Values assigned using the = operator

Variables ii

Examples
Use meaningful names

- Declaration

```
salutation = "Hello"
name = "Monty Python"
pi = 3.14159
```

- Usage

```
print(name)
```

Variables iii

Variables and values can be combined

```
a = 3
b = 8.3
c = a + b
print(c)

salutation = "Hello"
name = "Monty Python"
print(salutation + " " + name) # Keep this printing syntax in mind
```

Variables iv

Keywords - reserved words

You cannot name a variable with these names as they are protected by the language.

```
and, assert, break, class, continue, def, del, elif, else, except, exec,
finally, for, from, global, if, import, in, is, lambda, not, or, pass,
print, raise, return, try, while, yield
```

Operators

Order of precedence (kind of like PEMDAS)

- ()
- **
- unary + -
- * / % //
- binary + -
- <, >, <=, >=, !=, ==
- `not`
- `and`
- `or`

Comments

- Comments have no impact on the program
- Should explain the code
- A comment starts with a # character

Examples

```
# Declaring the name
name = "Philipp"
print(name) # Prints Philipp
```

How to Print to Console in Python

Printing is useful to provide feedback to the user or sometimes to debug your program. Printing different data types in the same print statement can be cumbersome.

- `print()` is the function to print something to console in python

```python
print("This prints just a string")
answer = 42
print(answer)  # Just print a number
print("Combining a string and a number: " + answer) # -> TypeError
print(f"Much cleaner way to print string and a number: {answer}")
```

Functions in Python

Functions i

Function are self contained modules of code that accomplish a specific task. They usually ”accept” input data and ”return” a result.

```
name = "Some name"
print(name) # Some name is used inside the print function -> the print
      function accepts the input and prints it to the console
```

- Functions can (and often do) also return a result (but the print function does not)
  - **return** statement
  - If a function has no explicit return statement it implicitly returns `None`

Functions ii

Examples

```
text = "Python programming language"
print(text) # Prints: Python programming language
text_length = len(text) # This function returns the length of the text
print(text_length) # Prints length of the string
```

Type Conversions i

Assume you want to program a calculator. In order to do this the user needs to be able to input his numbers and the program should be able to read this. Here comes the `input` function into play.

```
print("Add two numbers")
a = input("Please enter the first number ")
b = input("Please enter the second number ")

print("The result of the two numbers is: ")
print(a + b) # Something is wrong here
```

Type Conversions ii

Sometimes it is necessary to convert a variable from one data type to another (if possible). If you read data from a file into python, at first all the data is interpreted as strings even if your file only contains numbers.

In order to do mathematical analysis on these numbers, they need to be converted to the appropriate number type first.

- `int("32")`: Converts a string that holds a number to an integer
- `int("Hello")`: This doesn't work and it will throw a ValueError exception
- `float("313.333")`: Converts a string that hold a number to a float
- `str(32)`: Converts a number to a string

Type Conversions iii

Thanks to the f-string there is at least one need less to use explicitly converison functions:

Examples

```
a = 20
b = 10
res = a + b
print(f"The sum of {a} and {b} is {res}")
# used to look like this:
print("The sum of " + str(a) + " and " + str(b) + " is " + str(res))
```

Built-In Functions

https://docs.python.org/3/library/functions.html

Functions, First Library

Library import

```
import math
log_res = math.log(17.0)
sin_res = math.sin(45) # ??
```

- http://docs.python.org/library/math.html

Functions, First Library

Library import

```
import math
log_res = math.log(17.0)
sin_res = math.sin(45) # WRONG (well, not really, but not what we want)

sin_res = math.sin(math.radians(45))  # cos/sin etc take radians as
    arguments -> conversion from degree to radians necessary
```

- http://docs.python.org/library/math.html

User Defined Functions i

User-defined functions

- A function encapsulates some functionality
- Reduces complexity
- A function encapsulates some functionality
- Reduces complexity

```
def print_two_values(param1, param2):
  print(param1)
  print(param2)
```

- Syntax is important
  - Indentation
  - The colon

User Defined Functions ii

Examples

```
def line_separator():
  print("")

print("First Line")
line_separator()
print("Second Line")
line_separator()
print("Third Line")
line_separator()
print("Fourth Line")
```

- If we want to change the line separator to a dashed line we only need to change a single line of code

```
def line_separator():
  print("------------------------------")
```

User Defined Functions iii

Examples

- If the line seperator should output two lines we can define a new function that calls the `line_separator()` function twice

```
def two_lines():
  line_separator()
  line_separator()

print ("First Line")
two_lines()
print("Second Line")
```

User Defined Functions iv

Parameters and arguments

- Arguments are passed when calling a function
- Value of arguments is assigned to parameters

```
def print_sum(number_1, number_2):
  result = number_1 + number_2
  print(result)

print_sum(1, 3)
print_sum(10, 5)
```

User Defined Functions v

Parameters and arguments

- Parameters are variables valid within the scope of the function
- Variables that are defined in a function can only be seen inside that function
- Scope can be identified by indentation

```
def concatenation(param1, param2):
  concat = param1 + param2
  print(concat)

concatenation("Hello", "World")
print(concat) # NameError: name 'concat' is not defined
```

User Defined Functions vi

Conclusion

- A function can be called multiple times
- If some code can be reused, put it in a function so you need to write less code
  - Higher factorization
  - Less redundancy
  - Better maintenance
- Functions can also call other functions

User Functions with Return Values: return

Functions with return value i

- Some functions will return a value

```
# Python 3
answer = input("Do you like Python?")

# Python 2.7
# answer = raw_input("Do you like Python?")
```

- Our previously defined functions have never returned anything, but only printed something out

Functions with return value ii

return

- Functions that return a value use the return keyword

```
import math
def area(radius):
  result = math.pi * radius ** 2
  return result

print(area(10))
my_circle_area = area(8)
```

- Functions can return any valid data type

Naming Conventions & Debugging

Naming Conventions i

How to name your functions and variables (PEP8)

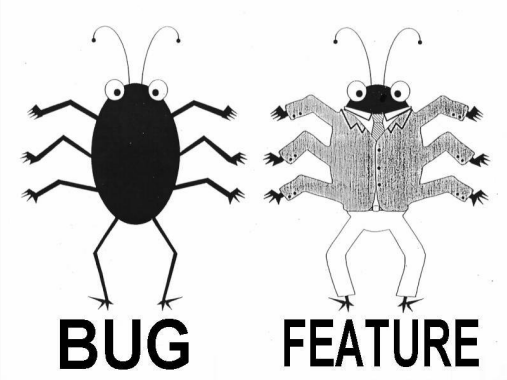
- Naming convention is a set of rules for choosing names of functions and variables
- Every programming language has different naming conventions
- Python
  - No spaces in variable and function names
  - Variable and function names are in lowercase and _ is used to separate words

```
length_in_cm = 15

def say_hello():
  print("Hello")
```

Debugging i

Finding and resolving ”bugs”



- Programming is a complex activity
- Mistakes happen all the time
- A mistake made in programming is called a bug
- The process of finding and resolving bugs is called debugging

Debugging ii

Errors

- Syntax error
  - Incorrect syntax of a statement: `print(Hello World)` instead of `print("Hello World")`
- Runtime error
  - Error that occurs during the execution of a program
  - e.g. division by 0
- Semantic errors
  - Program does not deliver correct results
  - No error messages (code is syntactically correct)
  - Fixing semantic errors can be extremely complicated (good software design is important)

Debugging iii

Techniques

- Reading code
- Print variables with `print()` to examine values (a poor man's debugger)
- Go through the program step by step -> **Debugger**!

Conditionals: if/else/elif

Conditionals i

- Boolean algebra is a part of mathematics
- Often used in programming
- A boolean expression is either true or false

```
5 == 5 # --> True
5 == 6 # --> False
6 > 4 # --> True
5 >= 8 # --> False
```

Conditionals ii

Examples

if

- The expression if defines a condition
- If the condition is true, subsequent statements will be executed
- If the condition is false, subsequent statements will not be executed
- There has to be at least one statement after the condition

```
x = 10
if x > 0:
  print(f"{x} is positive")
if True:
  # This statement will always be executed
  print("Yes")
if False:
  # This statement will never be executed
  print("No")
```

Conditionals iii

else

- Expression else is executed if the if condition is false
- Can only be used in combination with an if expression

```
if x == 0:
  print("x is zero")
else:
  print("x is not zero")
```

Conditionals iv

Examples

%-operator (remainder after division)

```
def print_parity(x):
  if x % 2 == 0:
    print("The number is even")
  else:
    print("The number is odd")

print_parity(2)
print_parity(3)
```

Conditionals v

Chained conditionals

- elif is used to combine multiple conditions
- The else expression is executed when neither if nor any of the elifs is true.
- Any number of elif expressions can be used but only one if and one else

Conditionals vi

Examples

```
if x < y:
  print(f"{x} is less than {y}")
elif x > y:
  print(f"{x} is greater than {y}")
else:
  print(f"{x} and {y} are equal")
```

```
# Python 3
answer = input("Do you like Python?")
# Python 2.7
# answer = raw_input("Do you like Python?")
if answer == "yes":
  print("That is great!")
else:
  print("That is disappointing!")
```

Functions with return value i

Boolean return values

- The functions can return a boolean value (True, False)
- The function name should be formulated as a yes/no question

```
def is_divisible(x, y):
  return x % y == 0
```

Functions with return value ii

Boolean return values

- The return value can be used in a condition

```
if is_divisible(x, y):
    print(f"{x} is divisible by {y}")
else:
    print(f"{x} is not divisible by {y}")
```

Exercise 1

Solve exercise 1

Conditionals i

Nested conditionals

- Conditionals can be nested

```
if x > 0:
  if x < 10:
    print("x is a positive single digit")
```

and

- Deep nesting can be difficult to read
- Use and to combine conditionals

Conditionals ii

```
if x > 0:
  if x < 10:
    print("x is a positive single digit")
# is the same as
if x > 0 and x < 10:
  print("x is a positive single digit")
```

or

- At least one statement must be true for the condition to be true

```
if x > 0 or x < 0:
  print("x is not zero")
```

Conditionals iii

not

- Negation, inverts the boolean.
- not True -> becomes False
- not False -> becomes True

```
if not (y == 0):
  print(x/y)
else:
  print("Cannot divide by zero")
```

X	Y	X and Y	X or Y
False	False	False	False
False	True	False	True
True	False	False	True
True	True	True	True

Exercise 2

Solve exercise 2

Exercise 3

Solve exercise 3

Lists: []

Lists i

- Lists are a data type
- Lists are used in most programming languages (arrays)
- Lists are a set of values

```
list_a = [1, 2, 4]
list_b = ["Monty", "Python"]
```

Lists ii

Creating lists

- The easiest way to create a list is using []

```
numbers = [10, 12, 14, 19]
words = ["spam", "bungee", "swallow"]
```

- Data types can be mixed

```
my_list = ["music", 2000, 3.5, True]
```

Lists iii

Creating lists

- Since numbers are often stored in a list, there is a special method for doing so
- With only one argument, range returns a number series starting at 0

```
list(range(4))
# returns [0, 1, 2, 3]
```

- When using two arguments it is possible to define the start and end of the range [start, end) (end is not included in the list)

```
list(range(1,5))
# returns [1, 2, 3, 4]
```

Creating lists

- The step size can be defined with a third argument

```
list(range(1, 10, 2))
# return [1, 3, 5, 7, 9]
```

- An empty list can also be created

```
empty_list = []
```

- This is often done when the values to be inserted in the list are not yet known.

Creating lists

- Accessing elements can be done with the [] operator

```
names = ["Anna", "Tom", "Ralph", "Peter"]
print(names[1])
# prints Tom
```

Important
Array indices start at 0!

0	1	2	3
Anna	Tom	Ralph	Peter

Accessing lists

- A negative index is used to access the list from the end

```
names = ["Anna", "Tom", "Ralph", "Peter"]
print(names[-1])
# prints Peter
```

Lists vii

Length

- The number of elementsi n a list can be obtained using the `len()` function

```
names = ["Anna", "Tom", "Ralph", "Peter"]
print(len(names))
# prints 4
```

Out of range

- If there is no item in the list at the desired index, Python will print an error message

```
names = ["Anna", "Tom", "Ralph", "Peter"]
n_names = len(names)
print(names[n_names])
# IndexError: list index out of range
```

Lists viii

Changing elements in a list

- An element can be changed using [INDEX]

```
names = ["Anna", "Tom", "Ralph", "Peter"]
names[0] = "Alice"
# ["Alice", "Tom", "Ralph", "Peter"]
```

Adding elements

- The `append()` method can be used t o add an element at the end of the list

```
numbers = list(range(5))
# [0, 1, 2, 3, 4]
numbers.append(5)
# [0, 1, 2, 3, 4, 5]
```

Lists x

Concatenate lists

- The + operator can be used to join lists

```
a = [1, 2, 3]
b = [4, 5, 6]
c = a + b
# [1, 2, 3, 4, 5, 6]
```

Slices

- Lists can be cut into slices
- The operator [n:m] returns a list of the elements that start at index n and stop before m

```
my_list = ["a", "b", "c", "d", "e", "f"]
my_list[1:3]
# ["b", "c"]
```

Slices

- If the first index is empty, the slice starts at the beginning

```
my_list = ["a", "b", "c", "d", "e", "f"]
my_list[:4]
# ["a", "b", "c", "d"]
```

- If the second index is empty, the slice will include elements until the end of the list

```
my_list = ["a", "b", "c", "d", "e", "f"]
my_list[3:]
# ["d", "e", "f"]
```

Deleting elements

- The `del()` method deletes items from the list

```
list_a = ["one", "two", "three"]
del(list_a[1])
# ["one", "three"]
list_b = ["a", "b", "c", "d", "e", "f"]
del(list_b[1:5])
# ["a", "f"]
```

Immutables: Tuples () and Strings

Tuples i

Tuples is an immutable sequence data type

- It is not possible to assign to the individual items of a tuple, however it is possible to create tuples which contain mutable objects, such as lists.
- Tuples are declared using () instead of []

```
tuple = ("a", "b", "c", "d", "e")
```

- Tuples containing only one element (singleton) must have a comma at the end of the definition

```
tuple = ("a", )
```

Strings i

Strings are immutable

- Unlike lists, strings cannot be changed
- Operations on strings always return a modified copy of the string
- The original string remains unchanged

```
greeting = "Hello, world!"
greeting[0] = "J"
# TypeError: 'str' object does not support item assignment
```

Iteration: for/while

Iterations i

- Iterations are used to repeat statements
- There are two expressions for iterations
  - while
  - for

while

- As long as the condition of the while loop is True, the body of the loop gets executed

Iterations ii

Example

```
def countdown(n):
  while n > 0:
    print(n)
    n = n - 1
  print('Lift off!')

countdown(10)
```

Iterations iii

while

- If the condition is False at the beginning, the body of the loop is never executed
- If the variable that is used to check the condition of the while loop does not change, the loop will never terminate -> infinite loop
- Whether a while loop terminates can be hard to determine

```
def sequence(n):
  while n != 1:
    print(n)
    if n % 2 == 0:
      n = n / 2
    else:
      n = n * 3 + 1
```

Iterations iv

while

- A while loop can be used to iterate through a list

```
names = ["Tom", "Anna", "Christopher"]
index = 0
while index < len(names):
  name = names[index]
  print(name)
  index = index + 1
```

Exercise 4

Solve exercise 4

Exercise 5

Solve exercise 5

Iterations

for

- Since it is often necessary to operate through lists and other data types, there is a special expression for this

```
for element in element_list:
  print(element)
```

Exercise 6

Solve exercise 6

Dictionaries: {}

Dictionaries i

Key-Value pair

- Dictionaries are very similar to lists but have a key and value for each entry
- The entries of a dictionary are not sorted

Dictionaries ii

Creating dictionaries

- Dictionaries are created using {}

```
eng2de = {}
eng2de["one"] = "eins"
eng2de["two"] = "zwei"
```

- Values can be added directly

```
inventory = {
"apples": 430,
"bananas": 312,
}
```

Dictionaries iii

Accessing entries

- Values can be accessed directly using dictionary[”key”]

```
inventory = {
"apples": 430,
"bananas": 312,
}
print(inventory["apples"])
# 430
```

Dictionaries iv

Assigning and modifying values

- The key is assigned a value
- If the key already exists the existing value is overwritten

```
inventory = {
"apples": 430,
"bananas": 312,
}
inventory["oranges"] = 530
inventory["bananas"] = 250
print(inventory["bananas"])
# 250
```

Deleting entries

- Key-Value pairs can be delted using the `del()` function

```
inventory = {
"apples": 430,
"bananas": 312,
}
del(inventory["bananas"])
```

Dictionaries vi

Number of entries

- The `len()` function returns the number of entries

```
inventory = {
  "apples": 430,
  "bananas": 312,
}
len(inventory)
# 2
```

Dictionaries vii

Checking if an entry exists

- The in keyword can be used to check if a key exists in a dictionary

```
inventory = {
  "apples": 430,
  "bananas": 312,
}
if "apples" in inventory:
  inventory["apples"] += 100
else:
  inventory["apples"] = 100
```

Dictionaries viii

Iterating over entries

- The `items()` function combined with the for statement can be used to iterate through every key-value pair

```
for (my_key, my_value) in my_dict.items():
  print(my_key + ' : ' + my_value)
```

Exercise 7

Solve exercise 7

Exercise 8

Solve exercise 8

Exercise 9

Solve exercise 9

Persistence

Persistence

- So far no data has been saved in any of our examples
- All data was deleted from the memory as soon as our examples quit
- There are several ways to permanently store data on the hard disk
  - Database
  - Simple text files

Files i

Common procedure

- Open file
- Do something with the file
- Close the file - depending on syntax done automatically.

```
with open('my_file.txt', "mode") as file:
  # do some stuff
```

Files ii

Different modes

- The mode defines how the content of the file should be treated
- Modes
- ”r”: read only
- ”w”: write only
- ”r+”: read and write
- ”a”: append

```
# open a file in read/write mode
with open('my_file.txt', "r") as file:
  # do some stuff
```

Files iii

Write

- The write() function is used to write something into a file
- '\n' is used to insert a line break

```
with open('my_file.txt', "a") as file:
  file.write('First line of the write operation')
  file.write('This is a line with a new-line character at the end\n')
  file.write('This is another line, on a new-line below the previous one.\n
      ')
```

Files iv

Read

- A for loop can be used to read a file line by line
- `line.strip()` removes the trailing '\n'

```
with open('my_file.txt', "r") as file:
  for line in file:
    line = line.strip()
    print(line)
```

JSON i

Dictionaries/list in JSON

- file.write() only accepts strings as arguments
- If complex structures such as dictionaries or lists should be stored in a file, it's necessary the convert these structures into strings first
- An example of a standard used for this purpose is JSON (Javascript Object Notation)

```
import json
my_dict = {"one": "eins", "two": "zwei"}
my_dict_as_string = json.dumps(my_dict)
print(my_dict_as_string)
```

JSON ii

Convert JSON to dictionaries/lists

- Example of a string in JSON that is converted into a dictionary

```
import json
my_dict_as_string = '{"two": "zwei", "one": "eins"}'
my_dict = json.loads(my_dict_as_string)
print(my_dict)
```

Exercise 10

Solve exercise 10

Additional Resources

- How to Think Like a Computer Scientist from Allen Downey, Jeffrey Elkner, and Chris Meyers
- Learning with Python: Interactive Edition 2.0
  - `http://interactivepython.org/courselib/static/thinkcspy/index.html`
- Official Python Documentation
  - `http://www.python.org/doc/`
- Project Euler: Mathematical problems that can be solved programmatically
  - `http://projecteuler.net/`
- Platforms to prepare for coding interviews
  - `https://leetcode.com`
  - `https://www.interviewbit.com/`