Python Fundamental[1]

Overview

In this handout, we will cover the basics of Python statements, variables, identifiers, and the commonly used data types: integers, floating-point numbers, strings, and booleans. Understanding these data types is essential for performing arithmetic operations, handling textual data, and making logical decisions in programs. Additionally, we will explore fundamental control structures, including `for` and `while` loops, which allow for repeated execution of code blocks, as well as `if`, `else`, and `elif` statements for conditional decision-making. By mastering these basics, you will gain the foundational skills needed to write and understand simple Python programs.

1 Statements, Variables, and Identifiers

A **statement** is a command that tells the program to do something.

assignment of a value to a variable

```
x = 12
```

This **statement** creates the variable `x` and assigns it the value 12 using the assignment operator `=`. Here's another example:

addition of two numbers

```
1 + 2
```

This **statement** adds the numbers 1 and 2 using the addition operator `+`. Let's look at one more statement:

comparison of two numbers

```
5 > 3
```

This **statement** checks if `5` is greater than `3` using the comparison operator `>`.

Programs store and use data, which is kept in the computer's memory. A Python **statement** often contains one or more **variables**. A **variable** holds a value that you can use later in your program. In simple terms, a **variable** is a name that points to a value stored in the computer's memory.

[1] These notes and examples adapt the references listed at the end. They are compiled to fit the scope of this specific course.

assignment of different values to different variables

```
city_name = "Washington DC"
average_temperature = 18.3
num_of_parks = 24
is_coastal_city = False
```

In this snippet (small piece of code), `city_name`, `average_temperature`, `num_of_parks`, and `is_coastal_city` are all **variables**. We assign values to these variables using the `=` operator. Each line here is an assignment **statement**. You can later use these variables in your code to retrieve their values and update them by assigning new values. Notice that each of these variables stores different types of data. While `city_name` stores a text, `average_temperature` and `num_of_parks` store numerical values, whereas `is_coastal_city` stores a True/False kind of data.

Note 1 : Python is case-sensitive! This means `city_name` and `City_Name` are not the same.

Note 2: In all the above statements, there's a space on both sides of the `=` sign. This is recommended by the **style guide for python code** (PEP 8), which makes your code easier to read. You can read more about the **PEP 8 style guide** on the website:
https://www.python.org/dev/peps/pep-0008/
As we go through the course, you are expected to follow these rules.

An **identifier** is a name (like `city_name` or `num_of_parks` in the examples) that you create to name **variables**, **functions**, **classes**, etc.

Identifiers must follow these rules:

- Identifiers can be made up of letters (`a-z`, `A-Z`), digits (`0-9`), and underscores (`_`). Space is not allowed.
- Identifiers cannot start with a digit. For example, `1day` is invalid, but `day1` is valid.
- Identifiers can be as long as you want.
- You cannot use special symbols like `!`, `@`, `#`, `-`, etc. The dash `-` is used as the minus operator.
- **Keywords** cannot be used as identifiers. Keywords (such as `False`, `if`, `lambda`, and `import`) are reserved words in Python that have special meanings and cannot be used as names for variables or functions. [2]

Warning

Python has several built-in functions such as `print()`, `type()`, `sum()`, `len()`, `min()`, `max()`, and `id()`, among others. You will become familiar with these functions as you progress. Although it is technically possible to use these names as variable names, doing so is considered very poor programming practice and is strongly discouraged.

[2] For a full list of keywords, please refer to https://docs.python.org/3/reference/lexical_analysis.html#keywords. Alternatively, you can run

```
import keyword
keyword.kwlist
```

inside a `Jupyter Lab` cell. Yet, another alternative is to open the `Command Prompt` from `Anaconda Navigator` and run

```
python
help()
keywords
```

2 `print()` Function

A **function** is a pre-written block of code that performs a specific task. You can call a function by writing its name followed by parentheses `()`. Data given to a function inside the parentheses `()` is called an **argument**.

The `print()` function displays output on the screen.

`print()` function example

```
interest = "Data Analysis"
print(interest)
```

This code yields:

```
Data Analysis
```

In this example, `interest` is the argument passed to the `print()` function, and `print()` displays the value of this argument on the computer screen.

The `print()` function can accept more than one argument separated by a comma `,`.

`print()` function with more than one argument

```
city_name = "Washington DC"
print("Hi,", "Welcome to", city_name, ".")
```

This code yields:

```
Hi, Welcome to Washington DC.
```

In this example, `city_name` is a **string**[3], which is a sequence of characters enclosed in double quotes `"`. Here is another example

another `print()` example

```
num_1 = 5
num_2 = 6
result = num_1 * num_2
print(num_1, "*", num_2, "=", result)
```

This code yields:

```
5 * 6 = 30
```

`print()` function

`print()` is a built-in (ready-to-use) function that displays the output on the computer screen.

[3] **string** is python's text type and we will discuss it shortly.

3 Python Data Types

In Python, we can store different kinds of data in a variable. Different data types can perform different tasks. In the examples above, we have seen some of Python's most common four data types:

- my_name is a **string** (str),
- hourly_wage is a **floating-point number** (float),
- number_of_kids is an **integer** (int), and
- is_employed is a **boolean** (bool).

These types are often referred to as Python's **basic** data types because they store single values.
The following shows some of the most commonly used data structures in Python:

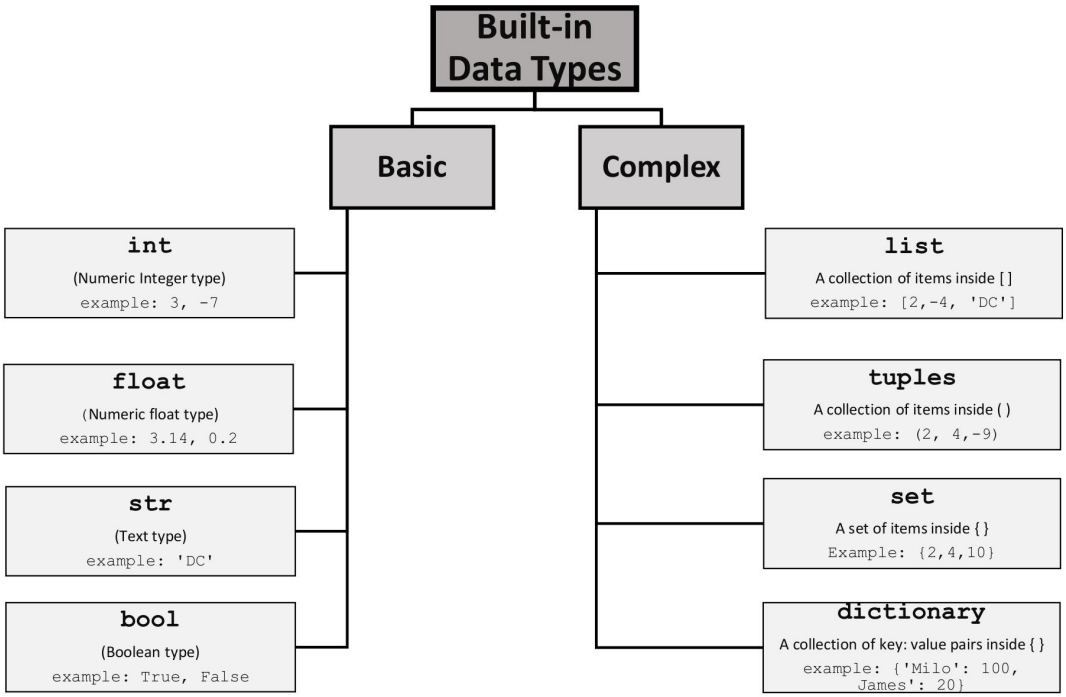


Figure 1: Most common data types

We will learn basic data types first before diving into complex ones. It is noteworthy that Python also has a data type called `complex` for handling complex numbers, which are written with a `j` as the imaginary part. We will not use this data type in this class.

3.1 `int`: Python's Numerical Integer Type

`int` is Python's built-in type for storing integer numbers. An integer is a whole number without a decimal point. The following example assigns an `int` to a variable:

assigning `int` value to a variable

```
number_1 = 15
```

This statement assigns the value 15 to the variable number_1 using the assignment operator =.
In Python 3, there is no limit to how large an integer can be (except by the memory available on your computer). For example:

testing `int` limit

```
x = 99999999999999999999999999999999999999999999999999999999999999999
y = x + 1
y
```

This code will yield:

```
1000000000000000000000000000000000000000000000000000000000000000000
```

You can check the type of a value or a variable using Python's built-in `type()` function. Here's an example:

using built-in `type()` function

```
x = 15
type(x)
```

This will return:

```
int
```

`type()` function

`type()` is a built-in function that returns the data type of a value or variable.[4]

3.2 `float`: Python's Numerical Floating Point Type

`float` is Python's data type for floating-point numbers (numbers with a decimal point). A `float` represents real numbers and is written with a decimal point separating the integer and fractional parts. For example, -30.6, 25.0, 10.79, 8e3, and 3.9e128 are all floating-point numbers. (Reminder: 8e3 = $8.0 \times 10^3 = 8.0 \times 1000 = 8000.0$).

using built-in `type()` function

```
z = 6.7
type(z)
```

This yields:

```
float
```

[4] a more accurate definition is: *`type` is a built-in function that returns the type of an object or variable.* We will learn the concept of Python objects later.

The maximum value of a `float` in Python is approximately `1.8e308`; any number greater than this will return the string `inf` (which stands for *infinity*). Similarly, the minimum value is about `-1.8e308`; numbers smaller than this are indicated by `-inf` (standing for *-infinity*).[5] Let's check this:

testing limit of `float` type

```
print(1.75e308)
```

This yields:

```
1.75e+308
```

However, if we try a number beyond the maximum:

testing limit of `float` type

```
print(1.8e308)
```

This yields:

```
inf
```

3.3 Arithmetic on `int` and `float`

We often need to perform basic arithmetic operations for data analysis. The table below summarizes the arithmetic operators in Python.

Python Operation	Arithmetic Operator	Algebraic Expression	Python Expression
Addition	+	$f + 7$	f + 7
Subtraction	-	$b - c$	b - c
Multiplication	*	$b \cdot m$	b * m
Exponentiation	**	x^y	x ** y
True division	/	$\frac{x}{y}$	x / y
Floor division	//	$\left\lfloor \frac{x}{y} \right\rfloor$	x // y
Remainder (modulo)	%	$r \mod s$	r % s

Table 1: Arithmetic operations on numerical values

A few hints:

- You can use the exponentiation operator to find the square root of a number! Remember that $\sqrt{47} = 47^{0.5}$.
- Floor division (//) divides a numerator by a denominator, yielding the largest integer that is not greater than the result. Hence, `10 // 4 = 2` and `-10 // 4 = -3`. (This is because `-10 / 4 = -2.5`, and the largest integer that

[5] If you are interested in where the `308` limit comes from, please check the https://en.wikipedia.org/wiki/Double-precision_floating-point_format on Wikipedia.

is not greater than -2.5 is -3.)

- Dividing by zero using / or // will result in a **ZeroDivisionError**.

3.4 Assignment Operators

In Python, you can use assignment operators to assign values to variables. Beyond the basic = operator, Python also supports **augmented assignment operators**. These operators allow you to perform a calculation and assign the result to the variable in a single step.

For example, instead of writing `x = x + 3`, you can use `x += 3`, which adds 3 to the value of `x` and assigns the result back to `x`. This is both simpler and more readable.

Here are the most common augmented assignment operators:

Algebraic Operator	Python Operator	Description	Python Example
$=$	=	Assign a value	`x = 5`
$+$	+=	Add and assign	`x += 3`
$-$	-=	Subtract and assign	`x -= 7`
$\times$	*=	Multiply and assign	`x *= 15`
$\div$	/=	Divide and assign	`x /= 2`

Table 2: Augmented assignment operators

In the table, the `+=`, `-=`, `*=`, and `/=` operators all work in a similar way: they perform an operation (addition, subtraction, multiplication, or division) on the variable and then assign the result back to the same variable. This makes your code more concise and easier to read.

3.5 `str`: Python's Text Data Type

3.5.1 `str` Basics

`str` is Python's text type. A string, or `str`, is a sequence of characters (symbols). Each letter in the English language is a character, but characters are not limited to just English letters! Any combination of characters forms a string. For example:

- 'stream'
- "stream"
- "Hello there!"
- "!!!"
- 'q@'
- "m"

are all strings.

A string in Python can contain as many characters as you want; the only limit is your computer's resources. You can surround a Python `str` with either single quotes ' or double quotes ". There is no difference between the two (e.g., 'stream' is the same as "stream"). Even though you can use either type of quotes, it's a good practice to be consistent.

You can display a `str` using Python's `print()` function. The `print()` function will not show the quotes around the string.

`print()` a string

```
print("Build for Whats Next.")
```

This yields:

```
Build for Whats Next.
```

However:

trouble with `print()`

```
print('Build for What's Next.')
```

yields a **SyntaxError**. Do you know why?

You can also begin and end a `str` with triple double quotes (""") or triple single quotes (''). The Python style guide recommends using triple double quotes. This can be used to create:

1. Long, multi-line strings
2. Strings containing single or double quotes
3. `docstrings`, which are used to document programs (we'll learn more about this later).

Try this:

printing strings with single quotes and double quotes

```
print("""Build For What's Next.""")
print("""Build For What's Next. 'This' Is How "We" Roll.""")
```

When a `str` contains a single quote, use double quotes around the string, and vice versa.

Alternatively, you can use an **escape character**. In Python, the backslash `\` is an escape character, and it forms an **escape sequence** when combined with the character that follows it. Here's a list of common escape sequences:

Escape Sequence	Description
\n	Insert a newline character
\t	Insert a horizontal tab
\\	Insert a backslash character
\"	Insert a double quote character
\'	Insert a single quote character

Table 3: Escape sequences

**use escape character **

```
print("Build \nFor \nWhat's \tNext.")
```

This yields:

```
Build
For
What's Next.
```

A `str` can be as long as you need, but writing a long string on one line might reduce readability. You can use a backslash `\` at the end of a line to split a long string across several lines without breaking it into multiple lines. For example:

printing a long line

```
print("You just finished your first semester.\
This semester you are taking four classes.\
During Spring 1 you will take four classes, as well.")
```

This yields:

```
You just finished your first semester.This semester you are taking four classes.During Spring 1 you will take four classes, as well.
```

As mentioned, a string is a sequence of characters (symbols). You can find the number of characters in a `str` using Python's built-in `len()` function. Here is an example:

finding length of a string

```
s1 = "Data"
s2 = "Year 2025"
print("length of s1:", len(s1))
print("length of s2:", len(s2))
```

yields

```
length of s1:  4
length of s2:  9
```

`len()` function

`len()` is a built-in function that can return the number of characters in a string[6]

3.5.2 String Concatenation (Joining)

Attaching (joining) two strings using `+` operator to form a new string is called **string concatenation**.

[6]The `len()` function can also be used to find the number of items in sequences such as `list`, `tuple`, or collections such as `dict` and `set`. More on this later.

concatenating two strings

```
s1 = "2025 will"
s2 = " be great year"
print(s1 + s2)
```

This yields:

```
2025 will be great year
```

You can concatenate as many strings as you need.

3.5.3 `str()`, `int()`, `float()`, and `round()` Functions

Besides being a data type, `str()` is a useful function that converts non-string values into a `str`.

converting a number to a string

```
num_1 = 1.5
string_1 = str(num_1)
print(type(string_1))
```

This yields:

```
str
```

After converting a number to a `str`, you can no longer perform arithmetic operations on it unless you convert it back to a number using `int()` or `float()`. Let's learn more about these two new functions. `int()` is a function that converts a value to an integer, while `float()` converts a value to a floating-point number.

converting a string to an integer

```
str_1 = "10"
var_1 = int(str_1)
type(var_1)
```

This yields:

```
int
```

converting a string to a float

```
str_2 = "3.14"
var_2 = float(str_2)
type(var_2)
```

This yields:

```
float
```

By using `int()` and `float()`, you can convert strings back to numbers for performing calculations.

Now that we have learned about `int()` and `float()` function, let's look at `round()` function as well. The `round()` function is used to round a floating-point number to a specified number of decimal places. If no number of decimal places is provided, it rounds to the nearest whole number.

Syntax:

- `round(number)`: Rounds `number` to the nearest integer.
- `round(number, ndigits)`: Rounds `number` to `ndigits` decimal places.

rounding to the nearest integer using `round()` function

```
num_1 = 4.67
rounded_num_1 = round(num_1)
print(rounded_num_1)
```

this yields:

```
5
```

In this example, `round()` rounds `4.67` to the nearest whole number, which is `5`.

rounding to two decimal places using `round()` function

```
num_2 = 3.14159
rounded_num_2 = round(num_2, 2)
print(rounded_num_2)
```

this yields:

```
3.14
```

In this example, `round()` rounds `3.14159` to `2` decimal places, resulting in `3.14`.

`str()`, `int()`, and `float()`, and `round()` functions

`str()` function converts a value to a string.
`int()` function converts a value to an integer.
`float()` function converts a value to a floating-point number.
`round()` function rounds a floating-point number to the nearest integer or to a specified number of decimal places.

3.5.4 `input()` Function

`input()` is a Python built-in function for getting input from the user. This function always returns a `str`.

using `input()` function

```
input("What is your name?")  # This will ask the user to enter a name
```

Running this line will prompt the user to enter their name and return it as a string.

concatenating user input rather than calculations

```
input1 = input("Enter first number ")   # Asks the user to enter a number
input2 = input("Enter second number ")  # Asks the user to enter another number
print(input1 + input2)                  # Concatenates user inputs
```

Since the `input()` function always returns a `str`, this will concatenate the two inputs as a single string **input1input2**, rather than performing any calculations. To work with numbers, you'll need to convert the inputs to the appropriate type, using `int()` or `float()` for numerical inputs. Here's an example:

summing user input as `float`

```
# get user inputs and convert them to float
input1 = float(input("Enter first number "))
input2 = float(input("Enter second number "))

# print sum of user inputs
print(input1 + input2)
```

This will return the arithmetic sum of the two numbers.

3.5.5 Creating a String

So far we have seen several different way of creating a string. Let's review these six methods of creating a string in Python here:

Single Quotes

using single quotes to create a string

```
s1 = 'Yes'
```

Double Quotes

using double quotes to create a string

```
s2 = "Yes"
```

Triple Single Quotes (Useful for Multi-Line Strings)

using triple single quotes to create a multi-line string

```
s3 = '''Yes
python is
fun'''
```

Triple Double Quotes (Useful for Multi-Line Strings)

using triple double quotes to create a multi-line string

```
s4 = """Yes
python is
fun"""
```

`str()` Function

using `str()` to create a string

```
s5 = str(12)
```

Concatenation

using concatenation to create a string

```
s6 = "Carey " + "Business " + "School"
```

3.5.6 Comments

In the examples above, we used comments to explain the code and make it easier to read. Python ignores anything after a `#`, treating it as a comment. Comments are helpful for understanding your code later, and they also help others (like your TA or professor) follow your work.

These things can improve code readability:

- Comments
- Spaces
- Blank lines

Blank lines, spaces, and tabs are called **white space**. Python ignores most **white space**, but not all![7]

3.6 `bool`

3.6.1 `bool` Basics

Often in programming, we need to evaluate a statement. **Booleans** (or `bool`) represent one of two values: `True` or `False`. Python returns `True` if the statement is correct; otherwise, it returns `False`.

[7] Indentation using spaces is important in Python, which we will cover later.

checking boolean conditions

```
# Assign prices to three cryptocurrencies and check a few conditions
BitCoin, Ethereum, Ripple = 62_000, 3_000, 0.53  # Using _ for readability

print(BitCoin > Ethereum)  # True if BitCoin > Ethereum, otherwise False
print(Ripple >= Ethereum)  # True if Ripple >= Ethereum, otherwise False
print(Ripple != BitCoin)   # True if Ripple is not equal to BitCoin, otherwise False
print("Milo" == 'Milo')    # True if two strings are the same
print("Milo" == 'Milo ')   # False due to the extra space
```

This yields:

```
True
False
True
True
False
```

The `==` operator checks equality, which is different from the assignment operator `=`. Also, remember that white spaces inside quotation marks are part of the `str`, which is why the last statement is `False`!

3.6.2 Comparison Operators

`True` and `False` are Python keywords. A **condition** is a Boolean expression with a value of `True` or `False`. You can create conditions using the comparison operators in the following table:

Algebraic Operator	Python Operator	Sample Condition	Meaning
$>$	`>`	x > y	x is greater than y
$<$	`<`	x < y	x is less than y
$\geq$	`>=`	x >= y	x is greater than or equal to y
$\leq$	`<=`	x <= y	x is less than or equal to y
$=$	`==`	x == y	x is equal to y
$\neq$	`!=`	x != y	x is not equal to y

Table 4: Comparison operators

3.6.3 Boolean Operators `and`, `or`, and `not`

Keywords `and`, `or`, and `not` combine simple conditions into more complex ones.

using boolean operator `and`

```
age = float(input("Enter your age as a number between 0 and 150"))
serious_medical_history = input("Do you have a serious medical history? y/n").lower()
```

```
result = (age >= 55) and (serious_medical_history == "y")
print(result)
```

This snippet asks the user for their age, converts it to a float, and asks if they have a serious medical history. The input is converted to lowercase using the `lower()` function. The condition checks if the age is at least 55 and if the user has a serious medical history. It returns `True` if both conditions are met, otherwise `False`, and then prints the result.
You can also use `or` and `not` to create different conditions. Here's an example:

using boolean operators `or` and `not`

```
age = float(input("Enter your age as a number between 0 and 150"))
serious_medical_history = input("Do you have a serious medical history? y/n").lower()

result = (age < 55) or (serious_medical_history == "n")
print(not result)
```

The `result` will be `True` if the user is younger than 55 or does not have a serious medical history. The `not` operator then inverts the result before printing it.[8]

`lower()` and `upper()` functions

The `lower()` function converts all uppercase letters in a string to lowercase, leaving other characters unchanged. Similarly, the `upper()` function does the opposite by converting all lowercase letters to uppercase.

`and`, `or`, and `not` operators

The `and` operator returns `True` if both conditions are true.
The `or` operator returns `True` if at least one condition is true.
The `not` operator inverts the result, returning `True` if the condition is false.

3.7 More on Strings

3.7.1 Membership Operators: `in` and `not in` keywords

You can use the keyword `in` to check if a specific phrase or character is in a `str`. Similarly, the keyword `not in` checks if a phrase or character is absent. These are Python's membership operators.

using `in` and `not in` with strings

```
s1 = "Business Analytics"
s2 = "Isabella"
```

[8] Later on, we will see that Boolean operators are often used with conditional statements.

```
print("Analytics" in s1)
print("bella" not in s2)
print("Ness" in s1)
```

This yields:

```
True
False
False
```

`in` and `not in` operators

The `in` operator checks if a value exists within a sequence (like a string) and returns `True` if found. The `not in` operator does the opposite, returning `True` if the value is not present in the sequence.

3.7.2 Accessing Characters in a String

A `str` is a sequence of characters, and you can access each character using brackets `[]`. Each character has an integer index starting from 0.

accessing string characters by index

```
dog_name = "Milo, The Golden!"
first_char = dog_name[0]
second_char = dog_name[1]
fourth_char = dog_name[3]

print("1st character of", dog_name, ": ", first_char)
print("2nd character of", dog_name, ": ",  second_char)
print("4th character of", dog_name, ": ",  fourth_char)
```

This yields:

```
1st character of Milo, The Golden!  :  M
2nd character of Milo, The Golden!  :  i
4th character of Milo, The Golden!  :  o
```

The last character is at index `len(dog_name)-1` [9]. Try this:

accessing the last character of a string

```
last_char = dog_name[len(dog_name)-1]
print("Last character of", dog_name, "is ", last_char)
```

This yields:

[9] Alternatively, you can access the last character with index of -1. More on this later!

```
Last character of Milo, The Golden! is !
```

3.7.3 Immutability of a `String`

A `str` in Python is **immutable**, which means that once you create a string, you cannot change its individual characters. Any attempt to modify a character of a string will result in an error. This immutability helps ensure that strings remain consistent and predictable throughout your program.

For example, if you try to change a character in a `string` using assignment operator `=`, like this:

Immutability of a `string`

```
str_1 = 'Care'
str_1[1] = 'o'  # Try to replace 'a' with 'o'
```

It will produce the following error:

```
TypeError:  'str' object does not support item assignment
```

The error indicates that you cannot modify characters within a string using indexing, as Python does not allow assignment to individual elements of an existing string.

Why is this Useful?

Immutability of strings means that when you manipulate strings, Python often creates new strings rather than modifying existing ones. This can make your code more predictable, as you can be sure that a given string won't change unexpectedly after it's created.

Creating a New String

If you want to modify a string, you need to create a new one. For example, to change the second character of `str_1` to `'o'`, you would do this:

Creating a new `string`

```
str_1 = 'Care'
str_2 = str_1[:1] + 'o' + str_1[2:]
print(f'Original string: {str_1}')
print(f'Modified string: {str_2}')
```

This yields:

```
Original string:  Care
Modified string:  Core
```

Here, `str_2` is a new string based on `str_1`, but with the character at index `1` changed to `'o'`. This approach keeps the original string unchanged, which is a key aspect of working with immutable types in Python.

3.7.4 Formatting Strings

An `f-string` (short for formatted string) allows you to insert variables or expressions directly into a string by placing them inside curly braces {}. This makes string formatting cleaner and easier to read.

Often, you may need to display output in a specific format. As a first example, let's display the sum of two integer numbers on the screen.

basic `string` formatting

```
number1 = 6
number2 = 10
print('Sum of', number1, 'and', number2, 'is', number1 + number2, '.')
```

This yields:

```
Sum of 6 and 10 is 16.
```

While this works, it's easy to make mistakes with commas, quotes, or spaces. A more Pythonic way to format strings is by using `f-strings`. With `f-strings`, you can directly insert variables and expressions into the string.

Let's redo the above example using `f-strings`:

formatting with f-strings

```
number1 = 6
number2 = 10
print(f'Sum of {number1} and {number2} is {number1 + number2}.')
```

This yields:

```
Sum of 6 and 10 is 16.
```

With `f-strings`, you simply put variables or expressions inside curly braces `{}`, and Python automatically replaces them with their values.

`f-strings` are very flexible. One common use is controlling the display precision of numbers.

controlling precision with f-strings

```
a = 1 / 3
b = f'{a:.4f}'
print(b)
```

This yields:

```
0.3333
```

In this case, `.4f` tells Python to format the number with 4 digits after the decimal point. You can change the number of decimal places by adjusting the `x` in `.xf`. The `f` specifies that the number should be displayed as

a `float`.
Here's another example that formats the value of `pi` to different levels of precision:

formatting pi with f-strings

```
pi = 3.14159265
formatted_Pi_1 = f'{pi:.2f}'   # two digits after the decimal
formatted_Pi_2 = f'{pi:.0f}'   # zero digits after the decimal
formatted_Pi_3 = f'{pi:.11f}'  # eleven digits after the decimal
print(formatted_Pi_1)
print(formatted_Pi_2)
print(formatted_Pi_3)
```

This yields:

```
3.14
3
3.14159265000
```

Notice that using `f-strings` allows us to display the value of `pi` with different levels of precision. However, this formatting does not change the original value of the `pi` variable; it merely controls how the value is displayed.

`f-strings` can also include function calls or expressions directly inside the curly braces. Let's see an example:

expressions in f-strings

```
print(f'The length of "Python" is {len("Python")}.')
```

This yields:

```
The length of "Python" is 6.
```

In this example, we call the `len()` function inside the f-string to get the length of the string "Python".

You can also align or pad your text using `f-strings`. For example, to align text to the left or right within a specific width, you can use:

alignment with f-strings

```
cheese_name = "mozzarella"
print(f'|{cheese_name:<15}|')  # Left-align within 15 characters
print(f'|{cheese_name:>15}|')  # Right-align within 15 characters
```

This yields:

```
|mozzarella     |
|     mozzarella|
```

In this example, `<` is used to left-align and `>` is used to right-align, with the specified width of 15 characters. `f-strings` also offer other powerful capabilities, such as formatting percentages, which we will discuss further throughout the semester.

`f-strings`

The `f-string` allows you to insert variables or expressions directly inside a string by placing them within curly braces {}. This makes string formatting easier, more readable, and flexible.

4 `help()` Function

The `help()` function is a built-in function in Python that allows you to learn more about variables, functions, modules, and other components. It provides helpful documentation and explanations about how to use a specific function or module. You can use `help()` to get information about any variable, Python function, or module. Let's see an example where we ask for help on the `print()` function:

using `help()` on `print()`

```
help(print)
```

This will display information on how the `print()` function works, along with its arguments and examples. If you are unsure about what a function does, the `help()` function is a quick way to understand its purpose and how to use it.

Note for JupyterLab users: In JupyterLab, you can use a shortcut by typing `?` after any variable, function, or module name to get quick information. For example, run `print?` in a JupyterLab cell to see a brief description of the `print()` function. You can use this with variables and modules too.

`help()` function

The `help()` function provides detailed information about variables, functions, and modules. It is a built-in way to access Python's documentation and understand how to use different components.

5 Program Control

5.1 Introduction

Solving any computational problem requires executing a set of actions in a particular order. An **algorithm** is a list of instructions used for performing tasks. A cooking recipe found in any cookbook is an example of an algorithm. Any recipe has a list of instructions (actions) and the order of these actions.

In the context of programming, an algorithm is a set of procedures used for solving a problem. Any algorithm contains:

- The actions to be executed
- The order in which these actions are executed

A Python program is a list of actions performed by the computer in a particular order. Python uses three different forms of program control for specifying the order of instructions:

- **Sequential execution**
- **Selection statement**
- **Repetition statement**

Most programs use a combination of these program controls.

Algorithm

In programming, an `algorithm` is a step-by-step process for solving a problem or performing a task using a sequence of instructions.

5.1.1 Sequential Execution

In sequential execution, as the name suggests, statements are performed in the order they are written. Here is an example:

sequential execution of average

```
x = 10
y = 20
temp = x + y
average = temp / 2
print(f"Average of {x} and {y} is {average}")
```

Python executes these instructions sequentially to find the average of two numbers.

5.2 Selection Statement

A selection statement executes code based on a condition (an expression that evaluates to either `True` or `False`). Here is an example:

selection statement based on grade

```
grade = float(input("Enter your grade"))
if grade >= 70:
    print(f"{grade} is a passing grade")
else:
    print(f"{grade} is a failing grade")

print("We are done!")
```

This snippet does not perform instructions sequentially. Only one of the 3rd or 5th lines will be executed based on the condition. If `grade >= 70` is `True`, Python skips the `else` block (line 5); and if `grade < 70`, Python executes the `else` block instead and skips line 3.

5.2.1 `if` Statement

An `if` statement runs a set of actions if a condition is `True` and skips them if the condition is `False`.[10]

In the example below, the user inputs a grade, and the program prints "Pass" and "Great job!" if `grade >= 70`.

`if` statement with grade

```
grade = float(input('Enter a grade'))
if grade >= 70:
   print('Pass')
   print('Great job!')
```

An `if` block is a group of statements that will only run if the condition is `True`.Every statement inside (below) the `if` block must be indented consistently. Python uses indentation (spaces or tabs) to define the structure of the code, so inconsistent indentation will cause an `IndentationError`.

5.2.2 `if . . . else` Statement

The `if . . . else` statement performs one action if a condition is `True`, and a different action if the condition is `False`. The following snippet shows different messages based on the grade received from the user.

`if else` statement with grade

```
grade = float(input('Enter a grade'))
if grade >= 70:
    print('Pass')
    print('Great job!')
else:
    print('Failed')
    print('Try harder next time')
```

Concise Alternative: When suites inside `if` and `else` are very short, you can put the whole `if . . . else` block in one line. Here's an example:

concise `if . . . else` statement

```
grade = float(input('Enter a grade'))
print('Pass') if grade >= 70 else print('Fail')
```

This snippet will take a grade from the user and print "Pass" if `grade >= 70`; otherwise, it will print "Fail".

[10] **A technical note:** The `if` condition can be any expression. Non-zero values are treated as `True`, while zero is treated as `False`. Non-empty strings are also `True`, while empty strings are `False`.

5.2.3 `if . . . elif . . . else` Statement

The `if . . . elif . . . else` statement runs only one of many possible actions depending on which condition is `True`. The keyword `elif` is short for `else if`.

The following snippet accepts a floating-point input from the user and prints the corresponding grade.

`if elif else` statement with grade

```
grade = float(input("Enter your grade"))
if grade >= 90:
   print(f"grade of {grade} will get you an A")
   print("Great job")
elif grade >= 80:
   print(f"grade of {grade} will get you a B")
elif grade >= 70:
   print(f"grade of {grade} will get you a C")
   print("Let's talk.")
else:
   print(f"grade of {grade} is not acceptable")
```

It is important to understand that only the action for the first `True` condition is executed, even if other conditions are also `True`. For example, if `grade = 93`, Python will run only the block for `grade >= 90` even though `93 >= 80` and `93 >= 70` are also true.

The `else` statement in `if . . . elif . . . else` is optional and handles cases where none of the conditions are satisfied.

5.3 Repetition Statements

Repetition statements (sometimes called loops) are used to repeat the same code multiple times in succession. Python has two types of loops:

- `while` **statement**: Repeats an action (or a group of actions) as long as a condition remains `True`. This is known as a condition-controlled loop.
- `for` **statement**: Repeats an action (or a group of actions) for a specific number of times. This is known as a count-controlled loop.

For a better understanding of the difference of these two loops, let's look at their basic syntaxes (structures). The basic syntax for a `for` loop is:

5.3.1 `while` Loop

A `while` loop repeats a block of code as long as a condition is `True`. The basic syntax for a `while` loop is:

```
while condition:
   statement(s)    # These statement(s) must be indented
```

Here's how a `while` loop works:

- Test the condition before the loop starts.
- If the condition is `True`, repeat the block again.
- If the condition is `False`, exit the loop.

  The following snippet keeps track of the user's total score. It will ask for scores and keep adding them to the total until the user decides to stop.

adding scores using `while` loop

```
total_score = 0
keep_going = "yes"

while keep_going == "yes":  # loop as long as the user wants to continue
    score = int(input("Enter your score: "))  # ask for a score
    total_score += score  # add the score to the total
    print(f"Total score so far: {total_score}")  # print the updated total
    keep_going = input("Add another score? yes/no").lower()  # ask if they want to
    ↪ continue

print(f"Final total score: {total_score}")
```

Be aware of infinite loops: The condition inside the `while` loop must eventually become `False`; otherwise, the loop will continue infinitely, known as an **infinite loop**. Here is a simple example of an infinite loop:

infinite loop counting up

```
i = 0
indicator = True
while indicator == True:  # This condition will always stay True
    print(f"i = {i}")
    i += 1                # Increment i by 1 each time
```

This loop will keep counting up forever, or until the computer crashes, because the condition `indicator == True` will never become `False`.
Now, here's a modified version with an exit condition:

`while` loop with exit condition

```
i = 0
indicator = True
while indicator == True:
    print(f"i = {i}")
    i += 1
    if i == 10:
        indicator = False
```

In this improved version, the loop will stop when `i == 10`, because the `indicator` variable is set to `False`,

breaking the loop condition.

`while` Loop

A `while` loop repeats a block of code as long as a condition remains `True`. It stops when the condition becomes `False`.

5.3.2 `for` Loop

A `for` loop repeats a block of statements for a specific number of times. The basic syntax for a `for` loop is:

```
for variable in some collection:
    statement(s) # These statements must be indented
```

The `for` statement executes its block of statements for each item in a collection of items.

Let's see a few examples.

`for` loop iterating over characters in a string

```
for item in "America":
    print(item)
```

This yields:

```
A
m
e
r
i
c
a
```

Reminder: A string is a sequence of characters. We can loop through these characters and access them individually.

`for` loop with a `list`[11]

```
for item in ["Good Dog", "Naughty Cat", "Loyal Dog"]:
    print(item)
```

This snippet will go through three different phrases `"Good Dog"`, `"Naughty Cat"`, `"Loyal Dog"` and print them individually yielding

[11] We will learn elaborately about `list` data structure later

```
Good Dog
Naughty Cat
Loyal Dog
```

`for` loop with `range`

```
for i in range(2, 5):  # range starts at 2 (inclusive) and stops at 5 (exclusive)
    print(i)
```

```
2
3
4
```

The `range()` function generates a sequence of numbers. In this example, `range(2, 5)` produces numbers starting from 2 (inclusive) and ending before 5 (exclusive), so it generates 2, 3, and 4.

`for` Loop

A `for` loop repeats a block of code for each item in a sequence, running the loop until all items are processed.

Side note: A Cool Property of the `print()` Function

You can use the optional `end` argument in the `print()` function to control how the output is displayed:

`for` loop with custom end

```
for item in "America":
    print(item, end="   ")
```

This yields:

```
A   m   e   r   i   c   a
```

Instead of printing each character on a new line, the `end` argument controls what is printed at the end of each output. In this case, instead of moving to a new line after each character, it prints each character with three spaces, determined by `end` argument, in between. This helps customize the output format.

I've noticed more frequently that people use underscores as identifiers. The underscore character `_` is valid for Python identifiers. Try:

using underscore as identifier

```
for _ in range(5):
    print(_)
```

It's worth noting that the underscore character `_` is frequently used as a valid identifier in Python. In some

cases, it is used when the value of a variable is not important. For example:

using underscore as identifier

```
for _ in range(3):
    print(_)
```

This yields:

```
0
1
2
```

In this example, the underscore `_` is used as a placeholder for the loop variable since we don't need to reference the actual value inside the loop. This is a common practice when the variable's value isn't needed but we still need to run the loop a certain number of times. For more on the underscore's role in Python, check out this reference on DataCamp: https://www.datacamp.com/community/tutorials/role-underscore-python#IV.

5.4 `range()` Function

The `range()` function is a built-in Python function that generates a sequence of numbers. It simplifies count-controlled `for` loops. The function can accept one, two, or three arguments:

- **With one argument:** `range(a)` produces a sequence from 0 up to, but not including, `a`. For example:

`range()` function with one argument

```
for i in range(3):
    print(i)
```

This yields:

```
0
1
2
```

- **With two arguments:** `range(a, b)` produces a sequence from `a` up to, but not including, `b`. For example:

`range()` function with two arguments

```
for i in range(2, 5):
    print(i)
```

This yields:

```
2
3
4
```

- **With three arguments:** `range(a, b, s)` generates a sequence from `a` up to, but not including, `b`, incrementing by `s`. If `a < b`, `s` must be positive. If `a > b`, `s` must be negative. For example:

`range()` function with three arguments

```
for i in range(2, 11, 3):
    print(i)
```

This yields:

```
2
5
8
```

`range()` function decrementing

```
for i in range(20, 5, -9):
    print(i)
```

This yields:

```
20
11
```

`range()` Function

The `range()` function generates a sequence of numbers, often used to control the number of iterations in a `for` loop.

5.5 Concept of an Iterable

We discussed earlier that a `for` loop is used for iterating over a sequence. The sequence to the right of the `in` keyword of the `for` statement must be an **iterable**. An iterable is something[12] that the `for` loop can go through, one item at a time, until there are no more items left. The most common iterables in Python are:

- A `string`
- A `range`
- A `list`
- A `tuple`
- A `dictionary`
- A `set`

[12] `object`, to be more accurate

We will gradually learn about each of these data structures in detail.

5.6 Nested Loop

A **nested loop** is a loop inside another loop. The "inner loop" will be executed one time for each iteration of the "outer loop."

nested loop example

```
adjectives = ['beautiful', 'fun', 'safe']
metropolitan = ['San Diego', 'New York City']
for adj in adjectives:
    for city in metropolitan:
        print(f"{city} is {adj}")
    print()  # print an empty line
```

This yields:

```
San Diego is beautiful
New York City is beautiful

San Diego is fun
New York City is fun

San Diego is safe
New York City is safe
```

In the outer loop, `adj` takes the value `'beautiful'`; then the inner loop goes through all the items in `metropolitan` and performs `print(f"{city} is {adj}")`. Once the inner loop is done, the outer loop prints an empty line using `print()`. This finishes the first iteration of the outer loop. `adj` then takes the value `'fun'` in the outer loop, and the inner loop starts over again. The repetition continues until there is no item left in the outer loop iterable.

Note: You can put any type of loop inside any other type of loop. For example, a `for` loop can be inside a `while` loop or vice versa.

`Nested` Loops

A `nested` loop is a loop inside another loop. The inner loop runs completely for each iteration of the outer loop.

5.7 Optional: `Break` and `Continue`

Python allows:

- Stopping the whole loop before going through all the items in the iterable (using `break`).
- Stopping the current iteration of the loop and continuing with the next (using `continue`).

- A `for` loop to have an `else` block as well.

These are not commonly used features in Python, but interested students can learn more from the official documentation at https://docs.python.org/3/tutorial/controlflow.html.

6 Concept of an `object` and a `class`

Python is an object-oriented language, meaning everything in Python is treated as an **object**. But what is an `object`? Simply put, an object is a value stored in the computer's memory. Every object contains some data and has the ability to perform actions (called `methods`).

For example, in the statement `name = "Milo"`, the value "Milo" is an object. The variable `name` points to (refers to) that object.

6.1 Methods

A `method` is a special function that belongs to an object and performs an action. You can use a method by attaching it to an object with a dot (`.`).

For example, the string "Milo" has a method called `upper()`, which converts all letters to uppercase.

string method `upper()`

```
name = "Milo"
print(name.upper())  # Call the method 'upper()' on the string 'Milo'
```

This yields:

```
MILO
```

6.2 Types and Classes

Every object in Python belongs to a **class**. A `class` is like a template that defines the behavior (methods) of objects of that type.

For example:

- Strings like "Milo" belong to the `str` class.
- Numbers like 100 belong to the `int` class.
- Decimal numbers like 99.8 belong to the `float` class.

You can use Python's `type()` function to check the class of an object:

checking object type

```
name = "Milo"
print(type(name))  # str class

age = 5
print(type(age))  # int class
```

```
weight = 22.5
print(type(weight))  # float class
```

This yields:

```
<class 'str'>
<class 'int'>
<class 'float'>
```

6.3 Methods and Classes

Objects that belong to the same class respond to the same methods. For example, both `'Spring'` and `'Fall'` are `str` objects, so they both respond to the `upper()` method.

using `upper()` on two strings

```
season1 = "Spring"
season2 = "Fall"
print(season1.upper())  # Both are strings, so upper() works on both
print(season2.upper())
```

This yields:

```
SPRING
FALL
```

Each data type in Python is associated with a `class`. For example:

- `x = 10` creates an object from the `int` class.
- `y = 99.8` creates an object from the `float` class.

By knowing the class of an object, you can understand which methods you can use with it!

`class`, `object`, and `method`

A `class` is a template for creating objects. An `object` is created from a class, and it contains data and functions (methods). A `method` is a function inside a class that defines what an object can do.

6.4 Creating and Deleting Objects

In Python, objects are created automatically whenever you assign a value to a variable. This variable then becomes a reference to the object.

Here's a simple example:

creating objects

```
name = "Milo"  # A new string object is created
age = 9        # A new integer object is created
```

In this example:

- `name` refers to a string object "Milo".
- `age` refers to an integer object 9.

These objects remain in memory as long as they are referenced by at least one variable. However, Python allows you to delete references to objects using the `del` keyword. This doesn't delete the object immediately but rather removes the variable's reference to it.
Here's an example of deleting an object reference:

deleting objects with `del`

```
adj = "Difficult"
del adj  # The reference to the object "Difficult" is removed
```

After using `del`, the variable `adj` no longer refers to the object. If you try to access `adj` after deletion, you will get an error.

```
NameError: name 'adj' is not defined
```

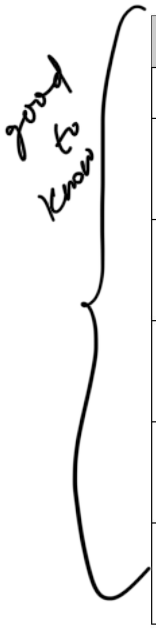
Python automatically deletes objects that are no longer referenced by any variable. This process is known as **garbage collection**. While you can use `del` to explicitly remove a reference, Python will take care of deleting the object when it's no longer needed.

`del` Keyword

The `del` keyword is used to delete a variable or object reference. Once deleted, the variable can no longer be used unless it is redefined.

6.5 `str` More Elaborate Methods

So far, we have seen the `lower()` and `upper()` methods for `string` objects. This section introduces additional methods, as listed in the following table.



Method	Sample Syntax	Description
`replace()`	`str.replace(old, new)`	Replaces occurrences of `old` with `new` in a string
`split()`	`str.split(separator)`	Splits a string into a list of substrings based on the `separator`
`join()`	`separator.join(iterable)`	Concatenates elements of `iterable` with the specified `separator`
`strip()`	`str.strip()`	Removes leading and trailing whitespace (or specified characters) from a string
`startswith()`	`str.startswith(prefix)`	Checks if the string starts with the specified `prefix`
`endswith()`	`str.endswith(suffix)`	Checks if the string ends with the specified `suffix`

Table 5: String Methods, Syntax, and Descriptions

6.5.1 `replace()` Method

The `replace()` method replaces occurrences of an old value with a new one in a string.

`replace()` usage

```
lie = "Java is a fun language"
truth = lie.replace('Java', 'Python')  # Replace 'Java' with 'Python'
print(truth)
```

This yields:

```
Python is a fun language
```

6.5.2 `split()` Method

The `split()` method splits a string into smaller pieces based on a separator.

`split()` usage

```
course_name = "Statistical_Analysis Python Operations_Management Simulation"
print(course_name.split())  # Split by whitespace
```

This yields:

```
['Statistical_Analysis', 'Python', 'Operations_Management', 'Simulation']
```

6.5.3 `join()` Method

The `join()` method concatenates elements of an iterable with a separator.

`join()` usage

```
words_1 = ['Are', 'you', 'ready', 'for', 'a', 'fun', 'semester', '?']
str_1 = ' '  # a space
print(str_1.join(words_1))  # Join words with a space
```

This yields:

```
Are you ready for a fun semester ?
```

6.5.4 `strip()` Method

The `strip()` method removes unnecessary characters from the beginning and end of a string.

`strip()` usage

```
str_1 = '      We are almost done with this handout           '
print(str_1.strip())  # Strip white spaces
```

This yields:

```
We are almost done with this handout
```

6.5.5 `startswith()` Method

The `startswith()` method checks whether a string starts with a specified value.

`startswith()` usage

```
dog_name = "Milo, The Naughty Golden Retriever!"
print(dog_name.startswith('Milo'))
print(dog_name.startswith('Golden'))
print(dog_name.startswith('Th', 6))  # Start search at index 6
```

This yields:

```
True
False
True
```

6.5.6 `endswith()` Method

The `endswith()` method checks if a string ends with a specified value.

`endswith()` usage

```
statement_1 = "Why do I have homework during my break?!"
print(statement_1.endswith('break?!'))
print(statement_1.endswith('!'))
```

This yields:

```
True
True
```

`str` Methods

- `lower()` converts all uppercase characters in a string to lowercase.
- `upper()` converts all lowercase characters in a string to uppercase.
- `replace()` replaces all occurrences of a specified substring with another substring.
- `split()` splits a string into a list of substrings based on a specified separator.
- `join()` concatenates elements of an iterable with a specified separator, returning a single string.
- `strip()` removes leading and trailing whitespace or specified characters from a string.
- `startswith()` checks if a string begins with a specified prefix.
- `endswith()` checks if a string ends with a specified suffix.

7 Python Standard Library

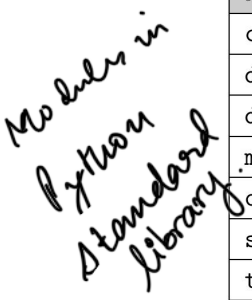
A **library** is a collection of reusable code that provides specific tools and capabilities. A **module** is a part of a library that can be used in your programs. Usually, a library consists of several modules.

Python comes with a **standard library** that includes many built-in modules, offering an extensive set of capabilities. Additionally, Python supports external libraries like `numpy` and `pandas` for more specialized tasks.[13] The following table summarizes some of the commonly used **modules** in Python's standard library:

These modules form a foundation for many types of tasks in Python, from file handling and data manipulation to system operations and statistical analysis. To use a module from the **standard library**, you must `import` it first.

A complete list of these capabilities is available at **Python Standard Library Documentation** available at https://docs.python.org/3/library/. Here are a few examples:

[13] A **module** is typically a single file that contains Python code, such as functions, classes, and variables, that can be imported and used in your programs. Libraries are made up of one or more modules.



Module	Application
`csv`	Processing comma-separated value files
`datetime, time`	Date and time manipulation
`decimal`	Accurate calculations
`math`	Common math constants and operations
`os`	Interactions with the operating system
`sys`	System-specific parameters and functions
`timeit`	Performance analysis
`random`	Random number generation
`statistics`	Statistical functions like mean, median, and variance
`string`	String processing
`json`	Working with JSON data
`re`	Regular expression pattern matching
`itertools`	Tools for working with iterators

Table 6: Python standard library modules

Example from `math` Module

using `math` module

```
import math                # import math module
print(math.pi)             # print pi
print(math.factorial(5))   # returns 5! = 120
```

This yields:

```
3.141592653589793
120
```

Example from `random` Module

using `random` module

```
import random                                          # import random module
print(random.choice(['Python', 'Java', 'Julia']))      # choose one randomly
print(random.random())                                 # a random number between 0 and 1
```

This yields (your answers will be different):

```
Julia
0.20713890285322634
```

Example from `statistics` Module

using `statistics` module

```
import statistics                                # import statistics module
print(statistics.variance([20, 12, 15, 11]))     # find sample variance
print(statistics.mean([20, 12, 15, 11]))         # find sample mean
```

This yields:

```
16.333333333333332
14.5
```

Example from `datetime` Module

using `datetime` module

```
from datetime import date  ## import date class from datetime module
now = date.today()         ## define now
print(now)
```

This yields:

```
2024-10-06
```

`Python Standard Library`

The `Python Standard Library` is a collection of modules that provide useful functions and tools to perform a wide range of tasks, from file handling to mathematical operations, without the need for external libraries.

8 Working with Precision: Understanding `Decimal` in Python

In this section, we will explore Python's `decimal` module, which allows us to perform highly accurate calculations, especially when precision is crucial.

8.1 Motivation

In everyday life, we use base-10 (decimal) numbers, which means we count in powers of ten (1, 10, 100, etc.). For example, the number 123 represents $1 \times 10^2 + 2 \times 10^1 + 3 \times 10^0$. Computers, however, use base-2 (binary), where everything is represented as 0s and 1s. This fundamental difference between how we naturally represent numbers and how computers store them can result in small inaccuracies when performing arithmetic operations with decimal values.

Let's see an example performing basic arithmetic calculations where results are displayed with 25 decimal places:

Floating-Point Arithmetic Example

```
print(f'1/2 with 25 decimal point precision is {1/2:.25f}')
print(f'1/3 with 25 decimal point precision is {1/3:.25f}')
print(f'1/10 with 25 decimal point precision is {1/10:.25f}')
print(f'0.1 + 0.2 with 25 decimal point precision is {0.1+0.2:.25f}')
```

This produces the following results:

```
1/2 with 25 decimal point precision is 0.5000000000000000000000000
1/3 with 25 decimal point precision is 0.3333333333333333148296163
1/10 with 25 decimal point precision is 0.1000000000000000055511151
0.1 + 0.2 with 25 decimal point precision is 0.3000000000000000444089210
```

Notice that while `1/2` is displayed accurately, the results for `1/3`, `2/9`, and `0.1 + 0.2` are slightly different from what we would expect. For example, `1/3` should ideally be `0.33333333333333333333333333`, but instead, it displays as `0.3333333333333333148296163`—a small yet noticeable discrepancy.

In Python, numbers with decimal points (like 0.1 or 2.75) are stored using a system called **floating-point representation**[14]. While this format is efficient for representing very large or very small numbers, it cannot store all decimal numbers with perfect accuracy. As a result, arithmetic operations with floating-point numbers can sometimes produce small rounding errors.[15] These inaccuracies are problematic when precision is critical, such as in financial calculations, scientific measurements, or any scenario where even small errors are unacceptable.

To address this, Python offers a special data type called `Decimal` from the `decimal` module. Unlike floating-point numbers, `Decimal` stores numbers as **base-10** fractions, similar to how humans naturally work with decimals, ensuring more accurate and precise results. Since every decimal number can be represented precisely in base-10, calculations like $0.1 + 0.2$ will result in exactly 0.3 without any extra rounding errors.

8.2 Using `Decimal`

To use the `Decimal` type, the first step is to import the `decimal` module and create `Decimal` object. These objects allow for precise arithmetic. Next, it is important to pass the number as a `string` rather than a floating-point number, since floating-point numbers may already contain precision errors.

Here's an example of using `Decimal` for accurate arithmetic:

Using `Decimal` for Precise Arithmetic

```
from decimal import Decimal

result = Decimal('0.1') + Decimal('0.2')
print(result)
```

In the example above, the numbers `0.1` and `0.2` are passed as strings to avoid any potential floating-point

[14] For more technical details, refer to https://en.wikipedia.org/wiki/Double-precision_floating-point_format

[15] Think of it like trying to represent the fraction $\frac{1}{3}$ in decimal format—it results in an endless repeating decimal (0.3333...), and any attempt to store it exactly will always involve some rounding.

rounding issues. The result is an exact representation of `0.3`, as shown below:

```
0.3
```

8.3 Operations Using `Decimal`

Like regular numbers, you can perform various arithmetic operations using `Decimal`.

Here's an example of using basic arithmetic with `Decimal`:

Arithmetic with `Decimal`

```python
from decimal import Decimal

# Arithmetic operations
a = Decimal('2.5')
b = Decimal('1.3')
addition = a + b
subtraction = a - b
multiplication = a * b
division = a / b

print(f'Addition: {addition}')
print(f'Subtraction: {subtraction}')
print(f'Multiplication: {multiplication}')
print(f'Division: {division}')
```

This yields:

```
Addition:  3.8
Subtraction:  1.2
Multiplication:  3.25
Division:  1.9230769230769231
```

`decimal` Module and `Decimal` Type

The `decimal` module provides the `Decimal` data type, allowing for precise base-10 arithmetic. It is especially useful in applications where accuracy is critical, such as financial and scientific calculations.

8.4 Why Not Use `Decimal` for All Calculations?

You may wonder why Python doesn't do all the calculations in base-10 using `Decimal`. Here is why: The main drawback of using the `Decimal` data type in Python is **performance**. Arithmetic operations with `Decimal` are slower compared to floating-point operations. This is because `Decimal` provides more precision and accuracy by performing base-10 arithmetic, which requires additional processing to avoid the rounding errors associated with floating-point arithmetic. While this trade-off is acceptable in applications where precision is critical, such as

financial calculations, it can be a disadvantage in scenarios where performance is more important.

Next Topic Preview

In the next handout, we will explore Python's collection data types, including `list`, `tuple`, `dictionary`, and `set`. These collections allow us to store multiple values together, making it easier to manage and manipulate groups of related data. Understanding these data types is crucial for more advanced data handling and efficient programming in Python.

9 Exercise Questions

1. Write a `for` loop to print the numbers from 1 to 5. Use the `range()` function.
2. Write a `while` loop that prints the numbers from 1 to 5.
3. Write a `for` loop to print each character in the string `"Hello DC"`.
4. Accept a number from the user using `input()` function. Then, use an `if` block to check if the number is positive or negative. Print `"Positive"` if the number is greater than zero; otherwise, print `"Not Positive"`.
5. Use a `for` loop to calculate the sum of all numbers from 1 to 10.
6. Generate 5 random integers between 1 and 10 using `random.randint()` inside a `for` loop. Import the `random` module first.
7. Write a `while` loop that keeps generating a random number between 0 and 1 until the number is greater than 0.8. Print each generated number.
8. Take a user's name using `input()` function. Use an `if . . . elif . . . else` block to check if a given string starts with `"A"`, `"B"`, or some other letter which in this case you should mention that the first letter of the name. Print a different message for each case.
9. Write a `for` loop to print the squares of numbers from 1 to 10. Use the `range()` function.
10. Write a program that takes a number as input and prints `"Even"` if it is even, and `"Odd"` if it is odd. Use the `%` (modulus) operator and an `if . . . else` block.
11. Write a `for` loop to print every third character of the string `"Python Programming is fun!"` starting from the first character.
12. Write a program that generates a random floating-point number between 0 and 10, rounds it to 2 decimal places, and prints the result. Use the `random` module and `round()` function.
13. Write a program that asks the user to enter a word, and then checks if the word contains the letter `"e"`. Print `"Contains 'e'"` if it does, otherwise print `"Does not contain 'e'"`. Use the `in` keyword.
14. Write a `while` loop that asks the user for a number and calculates the cumulative sum until the user enters `0`. Print the cumulative sum at the end.
15. Write a program that asks the user for a temperature in Celsius and converts it to Fahrenheit using the formula `F = C * 9/5 + 32`. Print the result using an `f-string`.
16. What is the difference between `=` and `==`?
17. Write a code that accepts 4 numbers from the user and prints *all equal* if they all are equal numbers and prints *not equal* if not all numbers are the same.
18. Import `random` module and generate 16 uniform random numbers between 0 and 1. You need to use `random.random()` function inside a `for` loop.
19. Import `random` module and generate 10,000 uniform random numbers between 0 and 1. You need to use `random.random()` function inside a `for` loop.
    (a) Find *sum* of these numbers.
    (b) Find *average* of these numbers. You need to find sum and divide it by 10,000.
    (c) Find *minimum* of these numbers? Did you get an exact 0 as the minimum?
    (d) Find *maximum* of these numbers? Did you get the exact 1 as the maximum?
20. Inside a `for` loop generate 5000 uniform random numbers between 0 and 1. Use an `if` block to print those numbers that are bigger than 0.5. How many numbers did you get?

21. There are several ways to generate standard normal random numbers. One method is to start with two uniform[0, 1] random numbers `U_1` and `U_2` and apply the following functions to get two standard normal random numbers:

$$Z_1 = \sqrt{-2\ln U_1}\cos(2\pi U_2)$$
$$Z_2 = \sqrt{-2\ln U_1}\sin(2\pi U_2)$$

    (a) Use `random` and `math` modules to generate two standard normal random numbers using the above formulas. You need to explore functions available to you in `math` module.
    (b) Using a `for` loop, generate 20 standard normal random numbers using the above method.
    (c) Using a `for` loop, generate 2000 standard normal random numbers using the above method and keep only the positive numbers. How many positive numbers did you get?
    (d) Inside a `while` loop generate enough random numbers to get the first number bigger than 3. How many numbers did you have to generate to get to the first number bigger than 3?
    (e) Inside a `while` loop generate enough random numbers to get the 5 numbers that either are less than -2.5 or more than 2.5. How many numbers did you have to generate to get this result?

22. We learned that `True` and `False` represent boolean values in Python. We know that computers store everything in memory using a **binary** format, which means only `0`s and `1`s. In this binary system, `True` is stored as `1`, and `False` is stored as `0`. Run this code to understand this behavior:

numerical values of `True` and `False`

```
print(f'True + True = {True + True}')
print(f'True + False = {True + False}')
print(f'False + False = {False + False}')
print(f'True * 5 = {True * 5}')
print(f'True > False = {True > False}')
```

    What do you observe? How do you think Python treats `True` and `False` when used in calculations, given that they are stored as `1` and `0` in memory?

23. It is very tempting to use `max`, `min`, `sum`, `type`, and `id` as variable names. This question is designed to show you why this is a terrible idea. Running the following code

trouble using built-in functions as variables

```
num_1 = 5
num_2 = 6
sum = num_1 + num_2
print(sum)
print(sum(1,3))
```

    will lead to `TypeError: 'int' object is not callable`. Why do you think that is the case?

24. We learned that we can compare numerical values using comparison operators such as `=`, `<`, `>`, `<=`, `>=`. This assignment will help you extend that to `str`. Run this code and try to understand how Python compares two `strings`

string comparisons

```
s_1 = "Adams"
s_2 = "James"
s_3 = "Zara"
print(f'{s_1} < {s_2} results in {s_1<s_2}')
print(f'{s_3} < {s_2} results in {s_3>s_2}')
```

How do you think Python compares two strings?

25. Using the `Decimal` data type, multiply `0.1` by `3` and display the exact result.
26. You are working on a financial application that requires precise interest rate calculations. Using the `Decimal` type, calculate the compounded value of an investment of $1,000 at an annual interest rate of 4.5%, compounded monthly, for 5 years. Use the formula:

$$A = P\left(1 + \frac{r}{n}\right)^{nt}$$

where:

- $P = 1000$ (the principal)
- $r = 0.045$ (annual interest rate)
- $n = 12$ (compounding periods per year)
- $t = 5$ (time in years)

Ensure precise calculation without any rounding errors.

10 Exercise Solutions

Solutions to these problems can be found on the following GitHub page:
https://tinyurl.com/3wekv7mt
You can also access the same link using the QR code below:

11 References

References and Resources

The following references and resources were used in the preparation of these materials:

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