Data Types, Errors and Debugging, Advanced Math Operations & Formatting Output

CSCI-UA.002
Data Types
Data Types

Python needs to know how to set aside memory in your computer based on what kind of information you want to store.

There are three basic types of data that we will be working with during the first half of the term:
- Strings (character-based data)
- Numbers
- Logical Values (True / False)
Numeric Data Types

• Integers
  • Whole numbers that do not contain a decimal point
  • Abbreviated as “int” in Python
  • Example: 5, -5, 100, 10032

• Floating Point Numbers
  • Numbers that contain a decimal point
  • Abbreviated as “float” in Python
  • Example: 5.0, -5.0, 100.99, 0.232132234
Numeric Data Types

• History Floating Point Numbers

In 1914, Leonardo Torres y Quevedo designed an electro-mechanical version of Charles Babbage's Analytical Engine, and included floating-point arithmetic. Called the Arithometer. In 1938, Konrad Zuse of Berlin completed the Z1, the first binary, programmable mechanical computer; it uses a 24-bit binary floating-point number representation with a 7-bit signed exponent, a 17-bit significand (including one implicit bit), and a sign bit. The more reliable relay-based Z3, completed in 1941, has representations for both positive and negative infinities; in particular, it implements defined operations with infinity, such as \(1/\infty=0\), and it stops on undefined operations, such as \(0 \times \infty\).
Numeric Data Types

• You can store numeric data inside variables that you create. Example:

```python
num_1 = 5       # this is an int
num_2 = 4.99    # this is a float
```

• Keep in mind that you do not use separators or symbols when storing numeric data. Example:

```python
num_3 = $5,123.99  # error!
```
What’s the data type?

5

5.5

“Hello”

“5.5”

2.975

2.0
Numeric Data Types

- Python is not a strictly typed language. This means that you don’t need to pre-declare what kind of data your variables will be holding.

- This is also called “dynamic typing”
## Data Types across languages

<table>
<thead>
<tr>
<th>Loosely Typed</th>
<th>Strictly Typed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Python</td>
<td>C</td>
</tr>
<tr>
<td>PHP</td>
<td>C++</td>
</tr>
<tr>
<td>JavaScript</td>
<td>Java</td>
</tr>
<tr>
<td>Perl</td>
<td>ActionScript</td>
</tr>
</tbody>
</table>
### Strictly Typed Languages - Examples

<table>
<thead>
<tr>
<th>ActionScript</th>
<th>Java</th>
</tr>
</thead>
<tbody>
<tr>
<td>var name:String = “Harry”;</td>
<td>String name = “Harry”;</td>
</tr>
<tr>
<td>var top_speed:Number = 50;</td>
<td>int top_speed = 50;</td>
</tr>
<tr>
<td>var gravity:Number = 9.5;</td>
<td>float gravity = 9.5;</td>
</tr>
</tbody>
</table>
User input and Math Expressions

• We can capture input from the user (via the input() function) and use that input in our calculations

• However, the input() function “returns” a string – this means that the data type that “comes out” of the input() function is a series of printed characters

• We need to convert the result of the input function from a string into one of the two numeric data types that Python supports (float and int)
Solution: The float() and int() functions

- float() and int() are data type conversion functions. They each take one argument and convert that argument into the specified data type.

- Example:

  ```python
  # ask the user for their monthly salary
  monthly_salary = input('how much do you make in a month?')

  # convert the salary into a float
  monthly_salary_float = float(monthly_salary)

  # calculate the yearly salary
  yearly_salary = monthly_salary_float * 12

  # print the result
  print ('that means you make', yearly_salary, 'in a year')
  ```
Nesting data type conversions

• In the previous example we performed our data type conversion in two lines

• We could have done that in a single line using a technique called “nesting”

• Example:

  mynum = float(input('give me a number!'))
<h3 class="headers2"><i>Course Materials</i></h3>

Self-paced modules (password = "elearning")

<ul>
  <li><a href="http://cs.nyu.edu/elearning/CSCI_UA_0002/module01.php" target="_blank">Self-Paced Module #1</a></li>
  <li><a href="http://cs.nyu.edu/elearning/CSCI_UA_0002/module02.php" target="_blank">Self-Paced Module #2</a></li>
  <li><a href="http://cs.nyu.edu/elearning/CSCI_UA_0002/module03.php" target="_blank">Self-Paced Module #3</a></li>
  <li><a href="http://cs.nyu.edu/elearning/CSCI_UA_0002/module05.php" target="_blank">Self-Paced Module #5</a></li>
  <li><a href="http://cs.nyu.edu/elearning/CSCI_UA_0002/module06.php" target="_blank">Self-Paced Module #6</a></li>
  <li><a href="http://cs.nyu.edu/elearning/CSCI_UA_0002/module07.php" target="_blank">Self-Paced Module #7</a></li>
  <li><a href="http://cs.nyu.edu/elearning/CSCI_UA_0002/module08.php" target="_blank">Self-Paced Module #8</a></li>
</ul>

Read these materials as they are assigned ... and when you are ready, take the appropriate quiz in NYU/Classes!

If you would like a complete list of the modules: All

<ul>
  <li><a href="http://cs.nyu.edu/elearning/CSCI_UA_0002/module01.php">Review topics and sample problems for Midterm #1</a></li>
  <li><a href="http://cs.nyu.edu/elearning/CSCI_UA_0002/module02.php">Review topics and sample problems for Midterm #2</a></li>
  <li><a href="http://cs.nyu.edu/elearning/CSCI_UA_0002/module03.php">List of keywords which will be provided to you for Midterm #2</a></li>
  <li><a href="http://cs.nyu.edu/elearning/CSCI_UA_0002/module04.php">Final exam review: terms and concepts</a></li>
  <li><a href="http://cs.nyu.edu/elearning/CSCI_UA_0002/module05.php">Final exam review: problem sets and solutions</a></li>
</ul>
Nesting data type conversions

```python
mynum = float(input('give me a number!'))
```
Programming Challenge

• Ask the user for two numbers. You can assume they will be floating point numbers.

• Compute the following and print it out to the user:
  • The sum of the numbers
  • The product of the numbers
  • The difference between the numbers
  • The first number divided by the second number
Programming Challenge - Coins

• Write a program that asks the user for a number of pennies, nickels, dimes and quarters

• Calculate the total amount of money that the user has and print it out
Programming Challenge – Subway Ride Calculator

- Write a program that asks the user for the value of their current Metrocard
- Compute how many rides they have left on their card. Only provide whole number results (i.e. you cannot have 3.5 rides left on a card)
Errors, Bugs and Debugging
The Software Error

"...an analyzing process must equally have been performed in order to furnish the Analytical Engine with the necessary operative data; and that herein may also lie a possible source of error. Granted that the actual mechanism is unerring in its processes, the cards may give it wrong orders."

- Lady Augusta Ada King, Countess of Lovelace (1843)
“It has been just so in all of my inventions. The first step is an intuition, and comes with a burst, then difficulties arise—this thing gives out and [it is] then that 'Bugs' — as such little faults and difficulties are called—show themselves and months of intense watching, study and labor are requisite before commercial success or failure is certainly reached.”

- Thomas Edison, 1878
"Debugging"

1947, Harvard Mark II Computer

0900 0:st time started
1000 Stoped 0:st time
1015 0:st time stopped
1100 Started Cosine Tape (Sine check)
1525 Started Multi Adder Test
1545 Relay #70 Panel F (Moth in Relay)

First actual case of bug being found.

0840 0:st time started
1700 Closed down.
“Debugging”

De-bugging a program is the process of finding and resolving errors.
Types of Errors

• Syntax errors: The code does not follow the rules of the language; for example, a single quote is used where a double quote is needed; a colon is missing; a keyword is used as a variable name.

• Runtime errors: In this case, your code is fine but the program does not run as expected (it “crashes”). For example, if your program is meant to divide two numbers, but does not test for a zero divisor, a run-time error would occur when the program attempts to divide by zero.

• Logic errors: These can be the hardest to find. In this case, the program is correct from a syntax perspective; and it runs; but the result is unanticipated or outright wrong. For example, if your program prints “2+2 = 5” the answer is clearly wrong 😞
Example Errors

print ("hello, world!")
print ("hello, world!")

Syntax error (delimiters don’t match)
Example Errors

Source

num = input ('give me a number: ')
num_float = float(num)
new_num = 10 + num_float
print (new_num)

Execution

give me a number: apple
Traceback (most recent call last):
File "/Users/HarryPotter/Documents/madlibs01.py", line 6, in <module>
    new_num = 10 + num
TypeError: unsupported operand type(s) for +: 'int' and 'str'
(that was a runtime error)

The program ran, but when given bad data it crashed
num_1 = float(input('give me a num: '))

num_2 = float(input('give me another num: '))

print('the sum is: ', num_1 - num_2)

give me a num: 5
give me another num: 2
the sum is: 3.0
(that was a logic error)

The program ran, but it didn’t do what it set out to do (i.e. it gave us the wrong answer)
Basic Debugging Techniques

- Set small, incremental goals for your program. Don’t try and write large programs all at once.

- Stop and test your work often as you go. Celebrate small successes 😊

- Use comments to have Python ignore certain lines that are giving you trouble
Advanced Math Operations
Division Operations

- Python contains two different division operators

- The "/" operator is used to calculate the floating-point result of a division operation

- The "/\" operator is used to calculate the integer result of a division operation (essentially throwing away the remainder). This operation will always round down.

- Most times you will use the floating point division operator ("/")
Division Operations

print (5/2)  # 2.5
print (5//2)  # 2
print (-5/2)  # -2.5
print (-5//2)  # -3
Order of Operations

- Python supports the standard order of operations (PEMDAS)
- You can use parenthetical notation inside your math expressions to group operations
- Ex: 
  
  \[
  \frac{(5+10+20)}{60} * 100
  \]
Programming Challenge

- Write a program that asks the user for three price values.
- Calculate the average price in a single variable and output it to the user.
Calculating an average in a single step

average_score = (100 + 50 + 88) / 300
Exponents

• You can raise any number to a power by using the "**" operator

• Example: 2^4

2 ** 4
Programming Challenge: Calculating the area of a square

Area = $s^2$

**(Area = length x width. For a square the length and width are the same.)**

Example:

6 in
Remainder Operator (modulo)

- The modulo operator ("%") returns the remainder portion of a division operation

- Example:

  5/2    # 2.5
  5%2    # 1
Programming Challenge: Time Calculations

Ask the user to input a number of seconds as a whole number. Then express the time value inputted as a combination of minutes and seconds.

Enter seconds: 110

That’s 1 minute and 50 seconds
Converting Math Formulas into Programming Statements

• Most math formulas need to be converted into a format that Python can understand before they can be evaluated
Converting Math Formulas into Programming Statements

10b

(3)(12)

4xy

\[ y = 3 \frac{x}{2} \]
Programming Challenge: Investment Planning

• In this exercise you will ask the user to input the following values
  • How much money they want to generate
  • An interest rate value
  • How long they’d like to invest their money

• Calculate how much they will need as an initial investment

Example:
• You will need _____ dollars to generate _____ dollars at _____ % over _____ years.
Programming Challenge: Investment Planning

\[
P = \frac{F}{(1 + r)^n}
\]

• \( P = \) Present Value
• \( F = \) Future Value
• \( R = \) Rate or Return
• \( N = \) Number of Years
Mixed Type Expressions

• Python allows you to mix ints and floats when performing calculations.

• The result of a mixed-type expression will evaluate based on the operands used in the expression
## Mixed Type Expressions

<table>
<thead>
<tr>
<th>Operand 1</th>
<th>Operand 2</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>int</td>
<td>int</td>
<td>int</td>
</tr>
<tr>
<td>float</td>
<td>float</td>
<td>float</td>
</tr>
<tr>
<td>float</td>
<td>int</td>
<td>float</td>
</tr>
</tbody>
</table>
Line Continuation

• Sometimes expressions can get to be very long

• You can use the “\” symbol to indicate to Python that you’d like to continue the expression onto another line

• Example:

```python
x = 5 + 2 / 7 \ 
    + 8 - 12
```

• This also works for print() function calls as well
Formatting Output with the print() function
Line endings

• When using the print() function you probably have noticed that Python automatically places a newline character at the end of each line

• You can override this behavior and have Python use a character of your choice by using the optional ‘end’ argument when using the print() function

• Example:

  print (‘one’, end=‘’)
  print (‘two’, end=‘’)

Separating print() function arguments

• By default, Python will place a space between arguments that you use in print() function calls.

• You can override this behavior by using the optional ‘sep’ argument.

• Example:

  ```python
  print (‘one’, ‘two’, sep=‘*’)
  # output: one*two
  ```
Combing both line endings and separators

• You can use both the ‘sep’ and the ‘end’ arguments at the same time in the same print() function call.

• Example:

```python
print ('a', 'b', 'c', sep='*', end='')
```
Escape Characters

- Most programming languages support an “escape character” that allows you to perform special actions inside the confines of a delimiter.

- In Python the escape character is the “\” character

- It causes Python to treat the next character as a “special” character – in most cases this means that you will ignore the next character and prevent it from interfering with your delimiter

- Example:

  print ('Hi, I\'m Harry Potter, your professor')
Escape Characters

• There are a number of special characters you can use in conjunction with the escape character to perform special string operations.

• Example – “\n” – forces a line break.

print (‘line 1\nline 2\nline 3\n’)

# line 1
# line 2
# line 3
Escape Characters

- Example – “\t” – forces a tab:

  ```python
  x = 5
  y = 4
  print ('X', '\t', 'Y', '\t', 'X*Y')
  print (x, '\t', y, '\t', x*y)
  ```

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>X*Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>4</td>
<td>20</td>
</tr>
</tbody>
</table>
Programming Challenge

• Write a program that asks the user to enter in 3 products and 3 prices.

• Format your output to look like the following:

  Product    Price
  product1   price1
  product2   price2
  product3   price3
String Concatenation

• You can’t “add” strings together, but you can “concatenate” them into a single compound string

• Example:

```python
a = input('first name')
b = input('last name')
c = b + ',' + a
print (c)
```
String Repetition

- You can also “multiply” a string by an integer value to produce a larger string

- Example:

  ```python
  lyrics = 'Fa ' + 'La ' * 8
  print(lyrics)
  ```

  # Fa La La La La La La La La La
The format() function
• The format() function can be used to format a string before you decide to print it out to the user

• format() takes two arguments – a number and a formatting pattern (expressed as a string)

• format() returns a string which can be treated like any other string (i.e. you can print it out immediately, store its value in a variable, etc)
The Format function

• The first argument passed to the format function is the item that you wish to format

• The second argument passed to the function is the formatting “pattern” you wish to apply to this item

• This pattern varies based on what you would like to do to the item in question

• Once the pattern is applied to the item the format function will return a string version of your item with the formatting pattern applied
One common use of string formatting is to generate a string that contains a known number of characters.

For example, say you have the strings “Harry” and “Computer Science”. You might want to generate output that looks like the following given these items:

Name  Department
Harry  Computer Science

In this case we need to ensure that the strings “Name” and “Harry” are the same width so that the strings that come after them (“Department” and “Computer Science”) line up correctly.
String Formatting

- You can use the format() function to “pad” a string with extra spaces at the beginning or the end of the string.

- For example:

  \[ x = \text{format('Harry', '<20s')} \]

  - This will generate a new string (x) that contains the string ‘Harry’ plus 15 spaces at the end of the string. The total length of the string in this case will be 20 characters.

  - The ‘<‘ character in the formatting pattern tells Python to left justify the string and place the extra spaces at the end of the new string.
String Formatting

• You can also have Python right justify the string and place the spaces at the beginning of the new string by doing the following:

```python
b = format('Harry', '>20s')
```
String Formatting

x = "Hello, World!"

y = format(x, '>{20s}')

print (x)

>> Hello, World!

print (y)

>>   Hello, World!
The format() function can also be used to generate a printable string version of a float or integer number.

format() takes two arguments – a number and a formatting pattern (expressed as a string).

format() returns a string which can be treated like any other string (i.e., you can print it out immediately, store its value in a variable, etc).
Limiting decimal precision

```python
a = 1/6
print (a)  # 0.16666666666666666

b = format (a, '.2f')  # 0.17
print (b)
```

```python
0.16666666666666666
0.17
```
Formatting patterns

\[ a = \frac{10000}{6} \]  
\[ b = \text{format}(a, \text{`.2f'}) \]  
\[ c = \text{format}(a, \text{`.5f'}) \]  
\[ d = \text{format}(a, \text{`,.5f'}) \]  
\[ e = \text{format}(a, \text{`>20,.2f'}) \]  

# format \( a \) as a 2 digit float
# format \( a \) as a 5 digit float
# 5 digit float + comma separators
# 2 digit float, commas + 20 character minimum field width, justified to the right
a = 0.52

print (format(a, '%'))  
52.000000%

print (format(a, '.2%'))
52.00%

print (format(a, '.0%'))
52%
a = 20000

print (format(a, ',d'))

print (format(a, '>20,d'))
Programming Challenge

• Write a program that generates the 2 times table, like this:

\[
\begin{array}{ccc}
N1 & \times & N2 & = & N3 \\
2 & 1 & 2 \\
2 & 2 & 4 \\
2 & 3 & 6 \\
2 & 4 & 8 \\
\end{array}
\]