Module 01: Introduction to Programming in Python

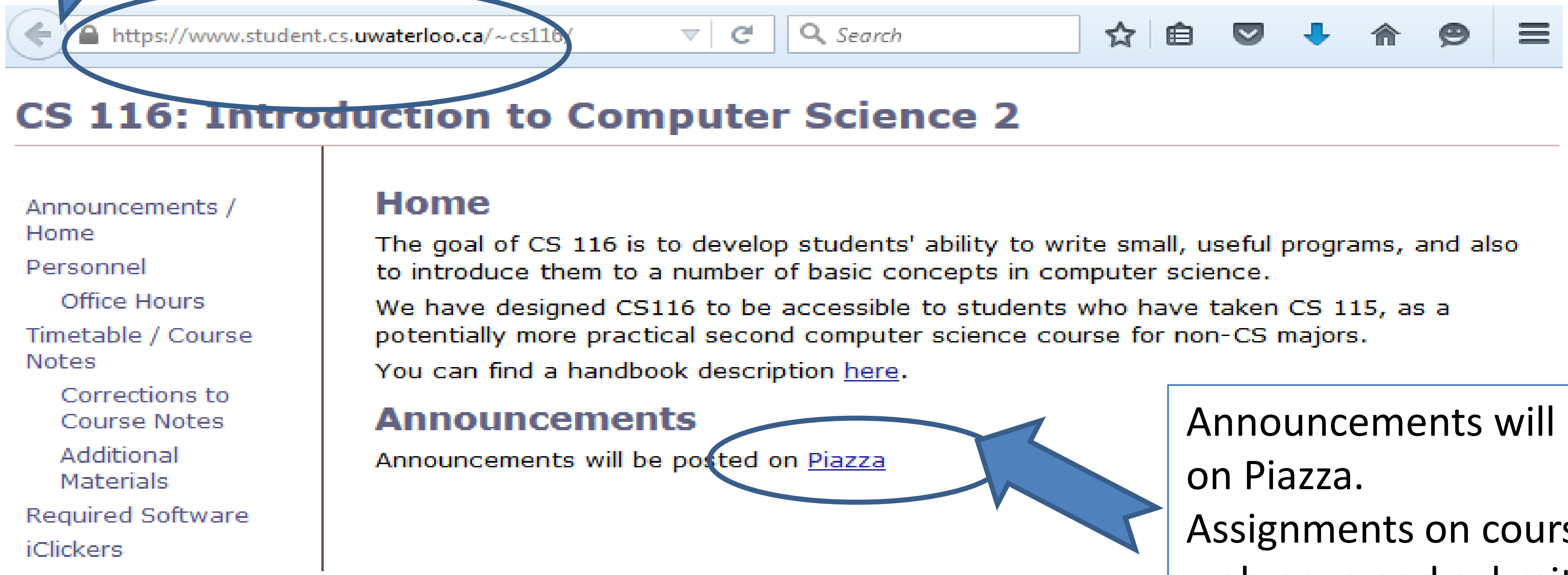
Topics:

- Course Introduction
- Introduction to Python basics

Readings: ThinkP 1,2,3

Finding course information

- https://www.student.cs.uwaterloo.ca/~cs116/



https://www.student.cs.uwaterloo.ca/~cs116/

CS 116: Introduction to Computer Science 2

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Home

The goal of CS 116 is to develop students' ability to write small, useful programs, and also to introduce them to a number of basic concepts in computer science.

We have designed CS116 to be accessible to students who have taken CS 115, as a potentially more practical second computer science course for non-CS majors.

You can find a handbook description here.

Announcements

Announcements will be posted on Piazza

Announcements will be on Piazza.
Assignments on course web page and submitted through MarkUs.

Important Administrative Details

- Announcements
- Weekly Tutorials
- (almost) Weekly Assignments
  - No extensions
  - Remark Policy: 2 weeks
  - **Submit code early and often**
  - Check your basic tests emails
  - Will drop lowest assignment grade
- Academic Integrity Policy
- AccessAbility Services

Grading

• Assignments	20%
• Participation	5%
(clicker questions with tutorial bonus)	
• Midterm	30%
• Final	45%

Note: You must pass the weighted average of the midterm and final in order to pass the course.

Major Themes from CS115

- Design
- Common Patterns
- Verification
- Communication

CS115 was not a course *just* about Racket!

Major Themes for CS116

- Design
- Common Patterns
- Verification
- Communication
- Algorithms

CS116 is not *just* a course about Python!

Introducing Python …

- We will learn to do the things we did in Racket
- We will learn to do new things we didn't do in Racket
- Why change?
  - A different programming paradigm
    - Racket is a functional programming language
    - Python is an imperative programming language
  - Design recipe still applies

What can Python programs do?

- Everything we did with Racket programs
- Lots of things we didn't cover in Racket

Functional vs Imperative languages in problem solving

- Much is the same: determine needed data types, variables, and helper functions.
- With a functional language like Racket:
  - Calculations are nested to show precedence
  - Calculated value is returned
- With an imperative language like Python:
  - Steps are separated, and ordered
  - Data values change as the program executes
  - Calculated values may (or may not) be returned

Running a Python Program

- Uses an interpreter like Racket (unlike most imperative languages)
  - Translates one statement at a time
  - Stops when one error is found
- Most imperative languages use a compiler
  - Translates entire program into machine code
  - Finds all errors in entire program
- Generally, harder to debug with a compiler but code typically runs faster.

What does a Python program look like?

- A series of statements
  - *Assignment statements*
  - *Control statements*
  - Function calls
- May include function definitions
  - Made up of statements
- May include new type definitions

Some Python Basics

- Written using regular mathematical notation

```
3 + 4
5 * (3 + 4) – 1
```

- Two numeric types (integers and floating point numbers) instead of one
- Strings, Booleans, lists
- No character or symbol type used in CS116.

Assignment Statements
`v = expr`

- **`=`** is the assignment operator ("becomes")
- **`v`** is any variable name
- **`expr`** is any Python expression
- How it works:
  1. Evaluate **`expr`**
  2. "Assign" that value to **`v`**
- Assignment statements do not return a value. They only have an effect.

A very simple Python program

```
x = 2 * (4 + 12)
y = x + 8
z = y * y
w = "hi"
u = w + w
```

What are the values of **`x, y, z, w, u?`**

Racket vs Python: Numeric types

- Numeric calculations in Racket were exact, unless involving irrational numbers
  - no real difference between **`3`** and **`3.0`**
- Integers in Python are stored exactly
- Other numbers are approximated by floating point values → Representation error
- Two different numeric types:
  - **`3`** is of type **`Int`**, but **`3.0`** is of type **`Float`**

Racket vs Python: Numeric types

	Racket		Python	
Value	*Representation*	*Type*	*Representation*	*Type*
natural	exact	**Nat**	exact	**Nat**
integer	exact	**Int**	exact	**Int**
rational	exact	**Num**	inexact	**Float**
irrational	inexact	**Num**	inexact	**Float**

Use these type names in Python contracts

Recall, in Racket:

- **`check-expect`** for testing exact values
- **`check-within`** for testing inexact values

More about
Racket vs Python: Numeric types

- Approximations are made at intermediate steps of calculations ➔ Round-off error
- **Do not** compare two floating point numbers for exact equality *(more later …)*
- **Do not** rely on floating point values being exact!
- Use **`Int`**, **`Float`**, or **`(anyof Int Float)`** in contracts, adding requirements as needed

Basic Mathematical Operations

- Addition (+), Subtraction (-), Multiplication (*):
  - If combining two **`Int`** values, the result is an **`Int`**
  - If combining two **`Float`** values, or a **`Float`** and an **`Int`**, the result is a **`Float`**

Basic Mathematical Operations

- Division: **`x / y`**
  - The result is a **`Float`** for any numerical values **`x`** and **`y`** (even if both are **`Int`**)
- Integer division: **`x // y`**
  - The result is the integer part of the division
  - If **`x`** and **`y`** are both **`Int`**, the result is an **`Int`**
  - If either **`x`** or **`y`** is a **`Float`**, the result is an **`Float`**, with the decimal part being **`.0`**
  - Usually used with **`x`** and **`y`** as **`Int`**

Other Mathematical Operations

- Remainder: **`x % y`**
  - **`x`** and **`y`** should both be **`Nat`**
  - returns the **`Nat`** remainder when **`x`** divided by **`y`**
- Exponents: **`x ** y`**
  - **`(anyof Int Float) (anyof Int Float) -> (anyof Int Float)`**
  - returns **`x`** raised to the power of **`y`**

More useful things to know

- Python precedence operations are standard math precedence rules (BEDMAS)
- Use ## or # for comments (from beginning or middle of line)
- Do not use dash in variable names
  - Use underscore instead

Calling functions in Python

`fn_name (arg1, arg2, …, argN)`

- built-in function or a user-defined **`fn_name`**
- must have correct number of arguments
- separate arguments by single comma
- examples:

```
abs(-3.8) => 3.8
len("Hello There") => 11
type(5) => <type 'int'>
max(3,5,9) => 9
```

The **`math`** Module

- A Python module is a way to group together information, including a set of functions
- The **`math`** module includes constants and functions for basic mathematical calculations
- To use functions from **`math`**
  - Import the **`math`** module into your program
  - Use **`math.fn`** or **`math.const`** to reference the function or constant you want

Type in the interactions window

```
import math
math.sqrt(25)
math.log(32,2)
math.log(32.0, 10)
math.floor(math.log(32.0, math.e))
math.factorial(10)
math.cos(math.pi)
sqrt(100.3)
```

Error!! Must use `math.sqrt(100.3)`

More `math` functions

```
>>> import math
>>> dir(math)
[…, 'acos', 'asinh', 'atan', 'ceil', 'cos',
  'cosh', 'degrees', 'e', 'exp',
  'factorial', 'floor', 'log', 'log10',
  'pi', 'pow', 'radians', 'sin', 'sqrt',
  'tan', 'trunc', …]
>>> help(math.floor)
Help on built-in function floor in module
  math:
floor(...)
    floor(x)
    Return the floor of x as an integer.
    This is the largest integral value <= x.
```

Creating new functions in Python

```
def fname (p1, p2, …, pN):
  statement1
  statement2
  …
  statementK
```

Notes:

- Indent each statement the same amount
- For function to return a value, include
  `return answer`
  where **`answer`** is the value the function returns
- If no return statement, the function returns **`None`**

Example: Write a Python function that consumes 3 different integers and returns the middle value.

```
# middle(a,b,c) returns the middle
#   value of a,b,c
# middle: Int Int Int -> Int
# requires: a,b,c are all different
# Examples:
# …
def middle(a,b,c):
    largest = max(a,b,c)
    smallest = min(a,b,c)
    mid = (a+b+c) - largest - smallest
    return mid
```

Review: Design Recipe for Functions

When writing functions in Racket, we included:

- Purpose statement
- Contract
- Examples
- Function body
- Test cases

We'll continue with these steps for Python programs.

Design Recipe (continued)

Some steps are the same in Python as in Racket:

- Purpose statement:
  - Explicitly indicate what the function does, including how the parameters are used
- Contract
  - Types of consumed and returned values
  - Include any needed requirements on parameters
  - Most type names are the same as in Racket, except for Num; Use Nat, Int, Float as appropriate

Design Recipe (continued)

Some steps are a bit different: Examples …

- We cannot write our examples as tests as we did in Racket, so a different approach is needed here.
- Our new approach:

```
# fn(arg1, arg2, …) => expected
```

- For example:

```
# middle(4,2,8) => 4
# middle(3,2,1) => 2
```

Design Recipe (continued)

- We will soon see that testing is similar, but different
- While templates are **not** required in CS116, you may still find them helpful, and we will try to point out common code patterns.

Design Recipe (summary)

Program design still involves creativity, but the design recipe can be very helpful:

- It provides a place to start.
- Contracts and purpose can reduce simple syntax errors.
- Good design and template choices can
  - reduce logical errors
  - provide better solutions

What goes in the body of a Python function?

- Assignment statements
  - May introduce new, local variables
- Calls to other functions
  - Built-in functions
  - User-defined functions
- **`return`** statement
  - Will be last code executed when present

We will learn more Python statements as we progress.

Using local variables in Python

In **`middle`**,

- **`largest`**, **`smallest`**, **`mid`**

are local variables.

They do not exist outside of middle.

More on local variables and functions

- A variable initialized inside a function only exists in that function
- If your function calls a helper function, the helper function cannot access the caller's variables
- Helper functions can be defined locally, but we will learn about that later
- Need only provide contract and purpose for helper functions

Example: Write a Python function to compute the area of a circle with nonnegative radius **r**

```
import math
# area_circle(radius) returns the area
#   of a circle with the given radius
# area_circle: Float -> Float
# requires: radius >=0
# Examples:
# area_circle(0.0) => 0.0
# area_circle(1.0) => 3.14159265

def area_circle (radius):
   return math.pi * radius * radius
```

Picky, picky, picky … Indentation in Python

A small change in indentation will lead to error

```
# tens_digit(n) returns the tens digit of n
# tens_digit: Nat -> Nat
# Examples:
# tens_digit(1234) => 3
# tens_digit(4) => 0
def tens_digit(n):
      div10 = n // 10
          tens = div10 % 10
  return tens
```

WARNING!! This example contains indentation errors!

Design Recipe: Testing in Python

- Our Python functions must still be tested
- Choosing test cases will be similar to before
  - Black box tests
    - Based on problem description
  - White box test
    - Based on actual implementation
- The mechanics of testing in Python will be different as Python does not have built-in **`check-expect`** or **`check-within`**

CS116 "**`check`**" Module

- Download the file: **`check.py`** from the CS116 web pages. Put a copy in the same folder as your **`.py`** files for each assignment.
- Add the following line to each assignment file:

```
import check
```

- You do NOT need to submit **`check.py`** when you submit your assignment files.
- A message is displayed for each test.

check.expect

```
## Question 1, Test 1: description
check.expect(
    "Q1T1",
    expr,
    value_expected)
```

Label the test

Actual result - usually a function call

Expected result;
Calculate it yourself

- This function performs the test:

Does **expr** exactly equal **value_expected**?

- Use for checking exact values (integer or strings).

check.within

```
## Question 2, Test 2: description
check.within(
     "Q2T2",
     expr,
     value_expected,
     tolerance)
```

Label the test

Actual result

Expected result

"Close enough" value

- This function performs the test:
  `abs(expr – value_expected) <= tolerance`
- Use for checking inexact values (floating point numbers only).

Testing **`middle`**

```
## Test 1: middle is first value
check.expect(
    "Q1T1",middle(3,10,1),3)
## Test 2: middle is second value
check.expect(
  "Q1T2",middle(2,5,9), 5)
```

Note: You should now include your examples with your tests.

Testing **`area_circle`**

`area_circle` returns a floating point

→Don't test for exact equality

Note: 0.00001 is typically a good **`threshold`** for our tests.

```
## Q2, Test 1: zero radius
check.within(
  "Q2T1", area_circle(0.0), 0.0, 0.00001)

## Q2, Test 2: positive radius (1.0)
check.within("Q2T2", area_circle(1.0),
  3.14159, 0.00001)
```

Investigating **`return`** further

```
def total_digits(secret):
    ones = secret % 10
    tens = secret // 10
    sum = ones + tens
    return
```

Assume ***`10≤secret≤99`***

```
>>> d = total_digits(74)
```

What is the value of **`d`**?

How would you write the contract of **`total_digits`**?

And even further

```
def total_digits(secret):
    ones = secret % 10
    tens = secret // 10
    sum = ones + tens

def calculation(secret):
    s = total_digits(secret)
    return secret - s

c = calculation(74)
```

Assume
$10 \leq secret \leq 99$

Warning: Continuing a Python statement over multiple lines

- Don't finish a line in the middle of a statement!
- Python expects each line of code to be an entire statement
  – Can be a problem e.g. due to indentation
- If a statement is not done, use a \ (backslash) character to show it continues on next line
  – Not needed if you have an open bracket on the unfinished line

More on Basic Types in Python

- Remember that the differences between integers and floating point numbers can complicate calculations
- Python has many built-in conversion functions from one basic type to another

How to get the type we want: More Casting and Conversion Functions

- **`float: Int → Float`**
  - `float(1) => 1.0`, `float(10) => 10.0`
- **`float: Str → Float`**
  - `float("34.1") => 34.1,`
  - `float("2.7.2") => Error`
  - `float("23") => 23.0`
- **`float: Float -> Float`**
  - `float(23.4) => 23.4`

More Casting Functions

- **`int: (anyof Float Str Int)`→ `Int`**
  - `int(4.7) => 4, int(3.0/4) => 0,`
  - `int(-12.4) => -12`
  - This is a truncation operation (not rounding)
  - `int("23") => 23`
  - `int("2.3") => Error`

- **`str: (anyof Int Float Str)` → `Str`**
  - `str(3) => "3", str(42.9) => "42.9"`

Goals of Module 1

- Become comfortable in Python
  - Basic types and mathematical operations
  - Calling functions
  - Defining functions
  - Using **`return`**
  - Design recipe in Python