ENGG1003

INTRODUCTION TO PROCEDURAL PROGRAMMING

STAFF

- Course Coordinator: Prof. Steven Weller
  - Steven.Weller@newcastle.edu.au
- Prof. Sarah Johnson
  - Sarah.Johnson@newcastle.edu.au
- Mr. Brenton Schulz
  - Brenton.Schulz@newcastle.edu.au
- See course outline for consultation hours
- Lab demonstrators
  - Too many to mention, you'll meet them in labs
  - Mix of postgrad and undergrad students
    - Ask them about their work, future studies, etc!

Steve

Sarah

BLACKBOARD

- Accessed via: http://uonline.newcastle.edu.au
  - Does anyone use QR codes? Didn't think so, have one anyway.
- All courses upload notes, lecture recordings, announcements, grades, etc. to Blackboard
- Your responsibility to check regularly, typically daily.

DISCORD

- We will be utilizing Discord
  - Invite link: https://discord.gg/sfgpR4kMbN
- Great for:
  - Quick questions
    - Much faster than email!
  - Connecting with peers
- Can be used as online consultation if Zoom doesn't work
- Staff will participate

COURSE CLASSES

- Two lectures per week – both via Zoom
  - This one (Mon 9-11am for those watching the recording)
  - Thursday 4-5pm
- Two computer labs - **Start this week!**
  - One on campus
    - You sit at a PC among 20-40 other students and get given tasks to do
    - Tasks distributed on Blackboard, typically a PDF, maybe template code
    - One or two demonstrators are paid to be there and answer your questions
  - One via Zoom – links will be on Blackboard

TEXTBOOKS

- S. Linge & H.P. Langtangen, Programming for Computations – Python (2nd edition), Springer Open, 2020. ISBN 978-3-030-16876-6 ISBN 978-3-030-16877-3 (eBook)
  - This textbook is an open access publication, available for free as an eBook via the University of Newcastle library.
  - Direct link: https://link.springer.com/book/10.1007%2F978-3-030-16877-3

THINKING OF DROPPING OUT?

- Come talk to us! What can be done to help?
- HECS Census: **19 March**
  - Last day to withdraw without financial or academic penalty
- Withdrawing between 20 March and 4 June does not incur academic penalty
  - You still pay for the course
- Withdrawing 12:00:01am on **5 June** or after results in a fail

WHERE TO FIND HELP

- Google
  - Copy/paste error messages
  - Search for Python tutorials (there are *lots*)
- Discord
  - A peer or staff member might be around to help you
- Your lab demonstrator
  - Only during enrolled lab times
  - They will help you do simple debugging, search for solutions, read documentation, etc
- The textbook

ASSESSMENTS

- Passing grade is 50%
  - Must also score 40% or higher in the final exam

Assessed Laboratory 1	Week 4,	5%
Mid-semester quiz	Week 6,	15%
Programming assignment 1	Week 7,	20%
Assessed Laboratory 2	Week 9,	5%
Assessed Laboratory 3	Week 11,	5%
Programming assignment 2	Week 13,	15%
Final Exam	Final exam period,	35%

ATTENDANCE

- An overall attendance of at least 80% is required for **on-campus labs**
  - ie: mandatory attendance applies to weekly 2-hour computer lab in ENGG1003
  - Uni-wide policy applies to all students in 1000-level courses e.g. ENGG1003
- Mandatory attendance does NOT apply to the weekly 1-hour Zoom lab
- Do NOT attend a lab if you are unwell!
  - Attending a later lab session does not require a medical certificate
  - If attending a later lab session, advise the demonstrator in that session

ASSESSMENTS

- Programming is quite unforgiving
  - If you develop code on a private machine it may not work on the university computers
  - Assessment demonstration on privately owned laptops is totally fine, if not preferred
- All assessments (except the final exam) are graded during your lab session
  - Assessment in a different lab session requires approval

WHAT IS "PROCEDURAL PROGRAMMING"?

- Telling a computer what to do via a list of steps
- Written in a language the computer can understand
  - Ideally, the human writing understands it too
- This course uses the language "Python"
  - Top language in IEEE survey multiple years running
  - Incredibly useful in isolation; fantastic platform to learn basics before learning other languages

WHY DO I NEED PROGRAMMING?

- ELEC/MECHA/Computer systems engineering
  - Embedded systems, programming small computers in home appliances, UAVs, wireless sensors, internet of things (IoT) devices, etc
    - You will all do this in ENGG1500 on the "STM32" microcontroller platform using microPython
  - Control systems – MATLAB (possibly also Python)
    - Designing mathematical models which make a thing do a thing
    - Eg: Car cruise control, temperature control, controlling robot arms, etc
  - Numerical methods
    - Catch-all term for any kind of heavy lifting arithmetic done on a PC or supercomputer
    - Applications typically quite specific

WHY DO I NEED PROGRAMMING?

- MECH/CHEM/Medical/Aerospace
  - Many of you will program embedded systems in C later on
    - Eg: MECH students use Arduinos in 2nd year
    - Almost all medical equipment is an "embedded" system
  - MATLAB is used extensively for various applications, Python slowly taking over
    - Ask your demonstrators in other courses?

WHAT IS A COMPUTER?

- How is this relevant to this course?
  - In order to write instructions (programming), you must have a relevant understanding of how computers work
- A computer is an electronic device designed to perform calculations very quickly
- This seems rather restrictive, just performing mathematics
- But when you consider its other capabilities
  - Speed
  - Communication with other electronic devices (peripherals)
- Then mathematics gives you
  - A word processor, sinus rhythms of a person's heart, how the ailerons should move to bank a plane, how a robot should weld a car body, how much heat is needed to maintain a chemical reaction, weather predictions, etc.

FUNDAMENTAL COMPONENTS

- Fundamental components of every computer

INPUT

- Computers only understand electrical signals
- More specifically those signals represent two states ON or OFF (binary 0 or 1)
- What about a keyboard?
  - It is a device which converts each keystroke into a series of ON/OFF voltages
- What about a mouse?
  - It is a device which converts movements into a series of ON/OFF voltages
- For our model we consider *input* to be
  - Any series of ON/OFF voltages which the computer needs to perform its calculations
- A device that generates input we will call an *input device*

PROCESSING

- *Processing* is the main function of a computer
- Once the input for a calculation is available, the computer will perform some processing
- Processing is a series of manipulations performed on the input
  - This involves following a very specific set of instructions
    - Instructions can be ADD, SUB, MUL, DIV, MOV, SQRT, etc…
  - The writing of those instructions is called *programming*

OUTPUT

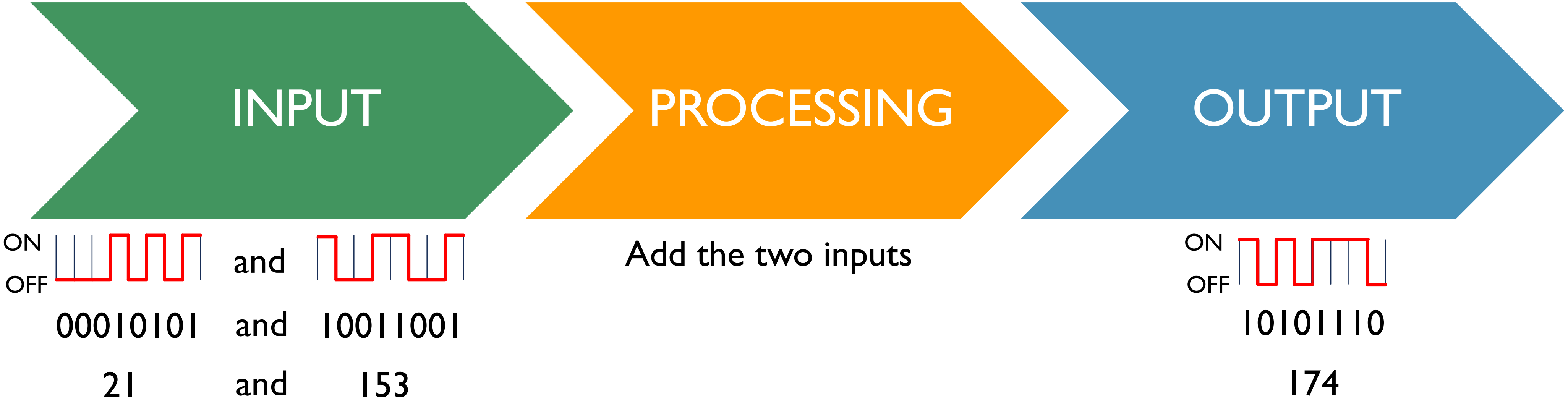
- Once the processing is complete
- The computer must have a way of presenting the results
- This is the *output*
  - Output is any series of ON/OFF voltages that represents the results of processing
- To make the output more useful we need an *output device*

OUTPUT

- An output device is any peripheral that takes a series of ON/OFF voltages and manipulates them into something useful or human readable
- Examples:
  - Printer
  - Monitor
  - Automotive cruise control throttle actuators
  - LCD showing the oxygenation level of a patient’s blood
  - Rudder adjustment in a fly-by-wire system

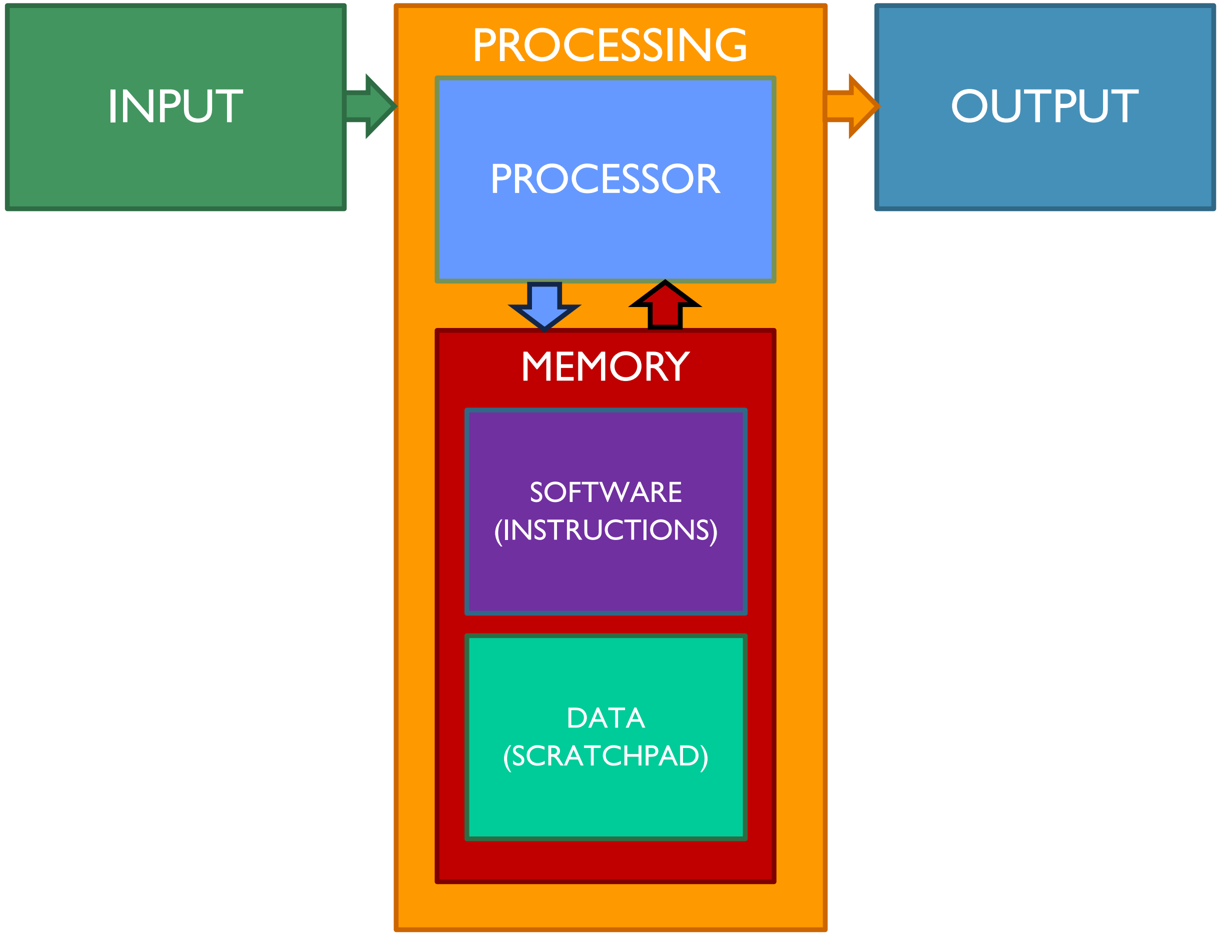
EXAMPLE FUNDAMENTAL COMPONENTS

- Fundamental components of every computer



PROCESSING IN DETAIL

- Processing is complex
- Requires multiple key sub-components to help
- For our purposes we define
  - PROCESSOR
  - MEMORY
  - SOFTWARE



PROCESSING IN DETAIL - PROCESSOR

- Processor
  - Performs mathematical and data manipulation tasks
  - Has sub-components, but they are not relevant for this course
    - More detail in ELEC1710

PROCESSING IN DETAIL - EVERYTHING IS A NUMBER

- Computers can only process numbers
- Things that aren't numbers need numerical "codes"
  - Text: ASCII and Unicode
  - Pictures: most commonly, each *pixel* is allocated a red-green-blue intensity value
  - Sound: the "waveform" is sampled at regular intervals and stored as a series of numbers
  - (NB: multiple standards exist for all the above)

PROCESSING IN DETAIL - MEMORY

- Memory
  - Like humans, computers need to store intermediate results
  - Memory acts like a set of written notes for the computer
  - Further relevant subdivision
    - Software – Instructions for the calculation
    - Data – The information required for the calculation

PROCESSING IN DETAIL - SOFTWARE

- Software
  - This is the main event for this course (the Python *interpreter*)
  - These are the detailed instructions that the processor will follow to perform the desired calculations
  - Instructions **directly** understood by the processor are
    - Very specific to each processor (known as the *instruction set*)
    - Limited in number
    - Simple, eg: add number in memory location 1 to the number in memory location 2 and put the result in memory location 3
    - Again each instruction is encoded as a series of ON/OFF voltages

SOFTWARE

- Software for our purpose will be divided into three groups
  - Machine code
  - Assembly language
  - "High level" languages

SOFTWARE – MACHINE CODE

- The processor can only understand machine code
  - Example, one instruction for an x86-based CPU
    - 0110 0110 1000 0011 1100 0000 0000 1010
    - Difficult for humans to understand
  - Very processor-specific
    - Will not be understood by another processor

SOFTWARE – ASSEMBLY LANGUAGE

- Assembly Language
  - Uses simple mnemonics to describe the purpose of the instruction
  - Example, one instruction for a x86 based CPU
    - Machine code: 0110 0110 1000 0011 1100 0000 0000 1010
    - Assembly language: `ADD AX, 10`
  - A bit easier for humans to understand
  - Still processor-specific

SOFTWARE – HIGHER-LEVEL LANGUAGES

- High level Languages (C, MATLAB, Java, Python, C++, FORTRAN,…)
  - Uses more human readable text-based code
  - Increases the complexity of each line of code so that common calculations can be done with fewer lines
  - Example, one instruction for a x86-based CPU
    - Machine code: 0110 0110 1000 0011 1100 0000 0000 1010
    - Assembly language: `ADD AX, 10`
    - In Python: `x = x + 10`
  - Much easier for humans to understand
  - Not processor specific
  - Allows writing of much more complicated instructions

RECOGNISING COMPUTERS

Device		Specification

Desktop PC		INPUT DEVICE: Keyboard and Mouse
		OUTPUT DEVICE: Monitor, Speakers
		PROCESSING:
		    PROCESSOR: Intel i7 64-bit CPU
		    MEMORY: 8GB RAM

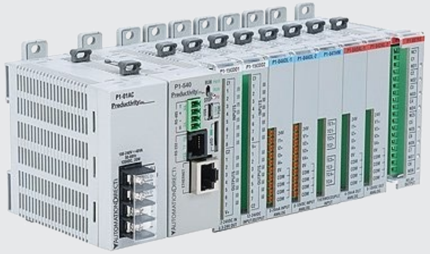
Laptop		INPUT DEVICE: Keyboard and Touch Display
		OUTPUT DEVICE: Monitor, Speakers
		PROCESSING:
		    PROCESSOR: Intel i7 64-bit CPU
		    MEMORY: 8GB RAM

Smart Phone		INPUT DEVICE: Touch Sensor, Microphone, Accelerometers, GPS receiver, 4G Receiver
		OUTPUT DEVICE: Display, Speaker
		PROCESSING:
		    PROCESSOR: Qualcomm Snapdragon 808 ARMv8-A 64-bit CPU
		    MEMORY: 8GB RAM

RECOGNISING COMPUTERS

Device	Specification
Raspberry Pi 3+ 	INPUT DEVICE: Keyboard, Electrical signals (I/O) OUTPUT DEVICE: HDMI Port to Display, USB, Audio PROCESSING: PROCESSOR: Broadcom BCM2837B0 64-bit quad-core ARM Cortex-A53 CPU MEMORY: 1GB RAM
Sony PlayStation 4 	INPUT DEVICE: Gaming Controller OUTPUT DEVICE: HDMI Port to Display PROCESSING: PROCESSOR: AMD x86-64 "Jaguar" CPU MEMORY: 8GB RAM
Apple TV 	INPUT DEVICE: Remote control OUTPUT DEVICE: HDMI Port to Display PROCESSING: PROCESSOR: Apple A10X Fusion ARM 64-bit CPU MEMORY: 2GB RAM

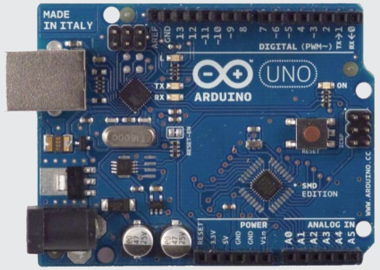
RECOGNISING COMPUTERS

Device	Specification
Smart TV 	INPUT DEVICE: Remote OUTPUT DEVICE: Display PROCESSING: PROESSOR: Dual-core ARM Cortex-A9 1Ghz MEMORY: 1GB RAM
PLC (Programmable Logic Controller) 	INPUT DEVICE: Electrical signals OUTPUT: Electrical signals PROCESSING: PROCESSOR: Intel 8051 CPU MEMORY: SOFTWARE: 2KB RAM DATA: 128B RAM
Defibrillator 	INPUT DEVICE: Electrical signals from electrodes OUTPUT: Defibrillation current PROCESSING: PROCESSOR: STM32 STM32F429 ARM-Cortex M4 32-bit CPU MEMORY: 256KB RAM

RECOGNISING COMPUTERS

Device		Specification

Network Router		INPUT DEVICE: Ethernet, Radio Signals
		OUTPUT DEVICE: Ethernet, Antennae
		PROCESSING:
		    PROCESSOR: Broadcom BCM21664T Dual-core ARM Cortex-A9 32-bit CPU
		    MEMORY: 1GB RAM

Arduino UNO		INPUT DEVICE: Electrical signals
		OUTPUT: Electrical signals
		PROCESSING
		    PROCESSOR: Microchip ATmega328 8-bit Microcontroller (CPU)
		    MEMORY:
		        SOFTWARE: 32KB RAM
		        DATA: 2KB RAM

RECOGNISING COMPUTERS

- All these devices are
  - Computers
  - Have the fundamental elements input, processing, and output
- What does this mean for you as a programmer?
  - Be aware that your target computer may have limitations
  - Different computers have different programming requirements

INTRODUCTION TO PYTHON – FUNDAMENTAL CONCEPTS

- Python is an *interpreted* language
  - This means an *interpreter* takes code from a text file or command prompt and converts it into machine instructions "on the fly"
  - Machine instructions are then *executed* by a computer
    - In this course "computer" will be a PC or laptop
    - Could be a microcontroller, mobile phone, supercomputer cluster, etc
- We will use the PyCharm integrated development environment (IDE)
  - Download "community edition" from: https://www.jetbrains.com/pycharm/download/#section=windows

INTRODUCTION TO PYTHON – FUNDAMENTAL CONCEPTS

- Moving data into and out of a Python program
  - *Standard input*: text characters read from a keyboard
  - *Standard output*: text characters sent to the screen
    - Typically printed to a *console*
  - *File I/O*: from or to files stored on a hard disk / USB flash drive / etc
    - Covered in later weeks

INTRODUCTION TO PYTHON –FUNDAMENTAL CONCEPTS

- Other input/output methods beyond this course:
  - Microcontroller pins (GPIO – in ENGG1500 and ELEC1710)
  - Embedded systems communication standards, covered in ELEC2720, ELEC3730, MCHA-something
    - I2C
    - SPI
    - UART
  - TCP/IP networking
  - USB devices
  - Loads of others

SOME BASIC PYTHON PROGRAMS

- Being an *interpreted* language Python programs can be just one line:
  - Examples (introduce PyCharm, run live!)
    - `print(“hello”)`
    - `1+1`
    - `print(1+1)`

SYNTAX

- What on Earth is *syntax*?
  - In human languages: the order of words in a sentence
    - Are you going to the movies on Tuesday?
    - Are you on Tuesday to the movies going?
  - In computer languages: the structure of the text given to the compiler
    - For example, `print(“hello”)` is different from `print(hello)` or `print hello`

SYNTAX

- The syntax rules in programming are typically **very** strict
- Incorrect syntax can result in Python generating syntax errors
- Eg:

```
>>> print("hello")
hello
>>> print hello
  File "<input>", line 1
    print hello
              ^
SyntaxError: Missing parentheses in call to 'print'. Did you mean print(hello)?
```

CASE SENSITIVITY

- Most programming languages are *case sensitive*
- This means that `print()` is **totally different** to `Print()` or `PRINT()`
- Fundamental reason: `p` and `P` are different ASCII characters
  - ASCII maps letters to numbers because computers only work with numbers

FUNDAMENTAL CONCEPTS – INPUT

- We saw `print()` for text output
- One function which reads *standard input* is `input()`
- It reads input text and converts it into other datatypes
  - Eg: converts the *text* "13" to the *number* 13
- Example: run `x = input("Type a number:")` followed by `print(x)`
- Huh? What was that `x` thing?
  - New fundamental concept: **variables**

FUNDAMENTAL CONCEPTS - VARIABLES

- A *variable* is something that stores data
  - "Data" is one or more numbers
  - Each variable needs a unique name
  - They are used to store numbers while your program runs
- Today we will run an example with *integer* variables
  - In Python 3.x integers have no (practical) upper limit
    - Factorial example later on
  - More details in the coming weeks

FUNDAMENTAL CONCEPT: ASSIGNMENT

- Computer languages use the = character for *assignment*
  - This is **distinctly different** from algebraic equality!
- Assignment means:
  - "Take what's on the right side and store it in the thing on the left"
  - You can read "`a = a + 5`" as "a **becomes** a plus 5“
    - The value of “`a+5`” is calculated and replaces the old value of `a`
- Eg: Give the variable `x` the value 2:
  - `x = 2`
- Eg: Add `a` and `b` together, store the result in `c`:
  - `c = a + b`

PUTTING IT ALL TOGETHER

- Example 1: Type Python commands which:
  - Reads 2 integers from the keyboard (from the "Python console")
  - Multiplies them together
  - Prints the result to the Python console
- Example 2: Type Python commands which
  - Reads an integer from the Python console
  - Calculates its factorial
  - Prints the result to the Python console
  - NB: This will use the math *library* – more on libraries next week

PUTTING IT ALL TOGETHER

- Repeat the previous 2 examples without using `input()` or `print()`
  - There are always multiple ways to solve the same problem!

WHAT NEXT?

- Install PyCharm "Community" edition
  - Download from: https://www.jetbrains.com/pycharm/download/
  - Installation details in Week 1 lab notes
  - Brenton has put together a short video stepping through PyCharm installation: https://bit.ly/3blcsoK
- Read textbook Chapter 1:
  - Direct link: https://link.springer.com/book/10.1007%2F978-3-030-16877-3
  - Run examples as you go!
- Read Week 1 lab notes
- Attend your on-campus and Zoom labs this week