Lab 03: Getting started with Python at Raspberry Pi

Raspberry Pi 3 comes with **NOOBS** – New Out Of the Box Software. You can purchase a pre-installed NOOBS SD card from many retailers, or download it for free. NOOBS is an easy operating system installer, which contains **Raspbian**. It also provides a selection of alternative operating systems that are then downloaded from the internet and installed.

Raspbian is a free operating system based on **Debian** optimized for the Raspberry Pi hardware. An operating system is the set of basic programs and utilities that make your Raspberry Pi run. Debian is a Unix-like computer operating system that is composed entirely of free software, most of which is under the **GNU General Public** License and packaged by a group of individuals participating in the Debian Project.

As you boot up the Raspberry Pi, on the desktop you should see a Raspberry button in the top left. Click on this to see the different types of applications that come pre-installed on NOOBS. Next you want to click on Programming, and then click on Thonny Python IDE.

A new window should open up on your desktop. This program is called an IDE, which stands for Interactive Development Environment. This particular IDE is called Thonny.

The window that has opened consists of a shell. In the shell you can type Python code, and it will be executed straight away. Have a go at typing the following lines into the shell. Don't worry about the three chevron symbols (>>>), as these will be added for you by Thonny.

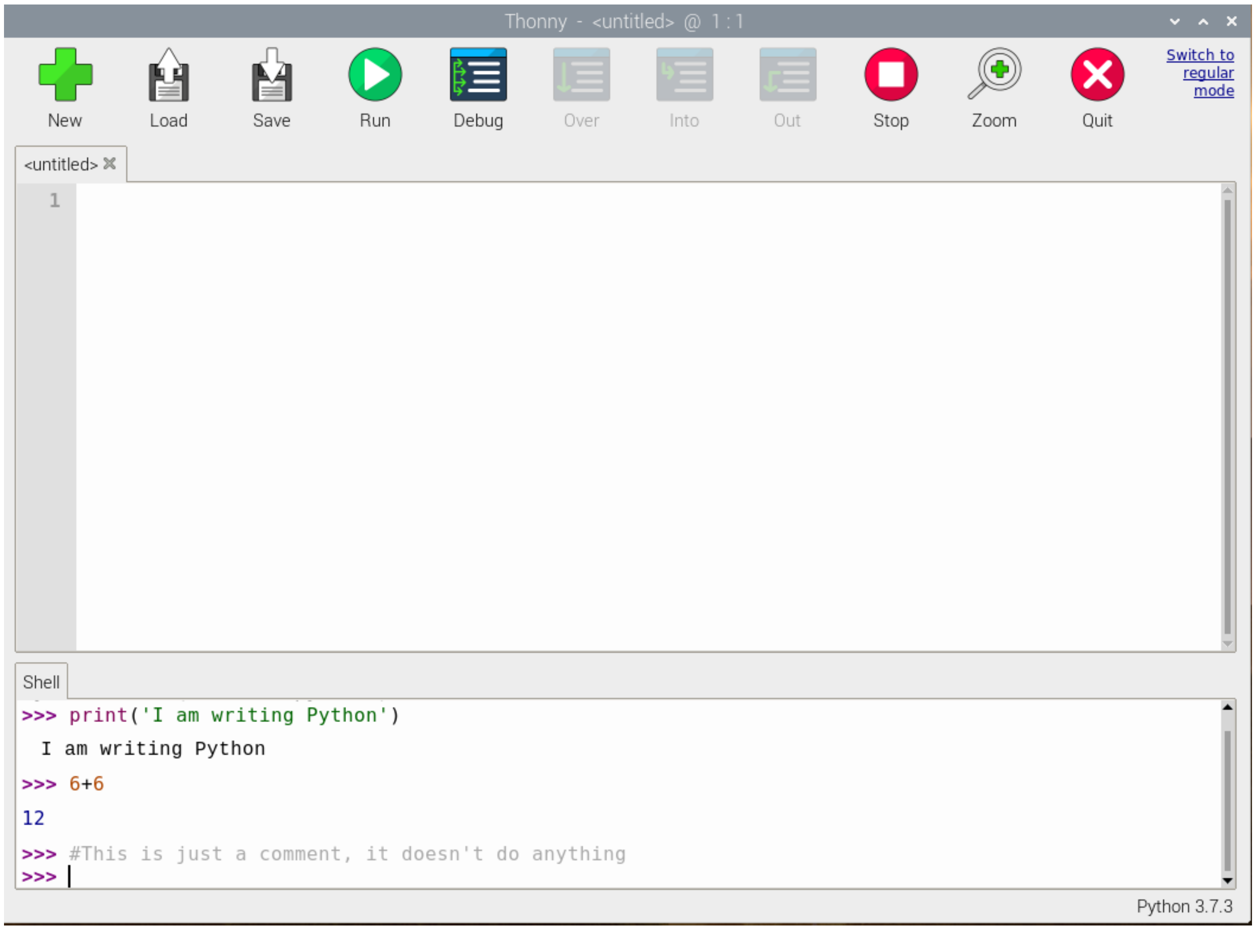
```
>>> print('I am writing Python')

>>> 6+6

>>> #This is just a comment, it doesn't do anything
```

The shell is useful for testing a few lines of code, or interacting with programs you have written, but to actually write a computer program, you need to write code into a file.

Another example is:

```
word1 = 'Hello   '
word2 = 'World'
print(word1 + word2)
```

Click on New button, and a new tab will open as Figure 1.



```
>>> print('I am writing Python')
 I am writing Python
>>> 6+6
12
>>> #This is just a comment, it doesn't do anything
>>> 
```

Figure 1: Thonny Python Window

Simple reaction game using inputs, outputs and variables

We can start with a very simple program that involves inputs and outputs and variables

```
print('Quick, the Enter key')
input()
print('That was fast')
```

Save your file (Save) and call it game.py. To run the file you can just press F5 on your keyboard.

The print functions are a type of output. You are instructing the computer to display some text on the screen.
The input function takes input from the user's keyboard presses.

Let's make the program a little more interesting. We could make the program pause for a little bit before it starts the game. Handling time can be a little tricky however, but luckily for us the code to interface with the computer's clock has been written for us and packaged up into a nice little module that we can use. To start with we only need one function from the time module. It's called the sleep function.

```
from time import sleep
sleep(5)
print('Quick, press the Enter key')
input()
print('That was fast')
```

Here you have imported the sleep function from the time module and then instructed the program to pause for five seconds.

Save and run your code to have a play with your new game.

It would be great to know how quick the user was between seeing the message and pressing the key. Again, the time module can be used for this, and in particular a function called time (confusingly!). We can add the import to our first line.

```
from time import sleep, time
sleep(5)
print('Quick, the Enter key')
input()
print('That was fast')
```

The time function will get the number of seconds that have elapsed since January 1st, 1970. By storing this value in a variable when the message is displayed, and then subtracting the time again, after the user has pressed a key, we can work out their reaction time. Here, the reaction time value is stored in the variable reaction_time. You can't have spaces in variable names, which is why we often use underscores.

```
from time import sleep, time
```

```
sleep(5)
start = time()
print('Quick, hit the Enter key')
input()
reaction_time = time() - start
print('You took', reaction_time, 'seconds')
```

Save and run your code, then have a play.

Working with loops

In Python you can use loops to make lines of code repeat. There are two types of loops - while loop and for loop. Below you can see examples of both.

```
while True:

    print('Hello')

    input()
```

This is a **while** loop which will repeat the indented lines of code until the condition is no longer true. In this case the condition is just the value *True* which will always be *True*, therefore this loop will never stop.

HINT : If you need to stop your program (an infinite loop for example) you can press ***Ctrl + C***

Another example of While True

```
# Another example of While loop

while True:
        x=input('Type a word containing multiple characters, or Type q to Quit the
    program.  ')
        if x== 'q':
            break
        if len(x)<4:
           print('You typed less than 4 character')
        if len(x)>4:
           print('You typed more than 4 character')
        if len(x)==4:
            print('You typed four character')
        continue
```

Another example of loop

```
for i in range(10):
    print('Hello')
    print(i)
    input()
```

This **for** loop is a finite loop and will loop a fixed number of times. For each value from 0 up to (but not including) 10, it will assign the value to the variable *i* and carry out the indented lines.

Notice that both loops need colons (:) added to the end of the line, and four spaces (or a 'tab') then need to be placed before the lines of code that are part of the loop. Try both of the mini programs out to see what the difference is between the two loops.

- Can you use loops in your game to make it repeat?
- Can you use variables to store the total reaction time after several games?
- Can you work out the average reaction time?

Note : The following link also gives some basic guide to using Python in Raspbery Pi (Look for Python in side headings).

https://www.raspberrypi.com/documentation/computers/os.html

General Purpose Input Output (GPIO) on the Raspberry Pi

The GPIO pins are a way in which the Raspberry Pi can control and monitor the outside world by being connected to electronic circuits. The Pi is able to control LEDs, turning them on or off, or motors, or many other things. It is also able to detect the pressing of a switch, change in temperature, or light etc. We refer to this as physical computing.

GPIO

Most models of the Raspberry Pi have 40 pins as shown in Figure 2.

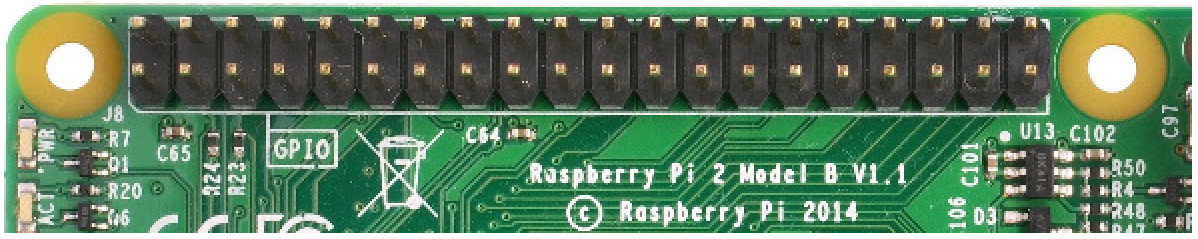


Figure 2: Physical GPIO pins of Raspberry Pi

These pins are a physical interface between the Raspberry Pi and the outside world. You can program the Raspberry Pi to switch devices on and off (output), or receive data from sensors and switches (input). Of the 40 pins, 26 are GPIO pins and the others are power or ground pins (plus two ID EEPROM pins which you should not play with unless you know your stuff!)

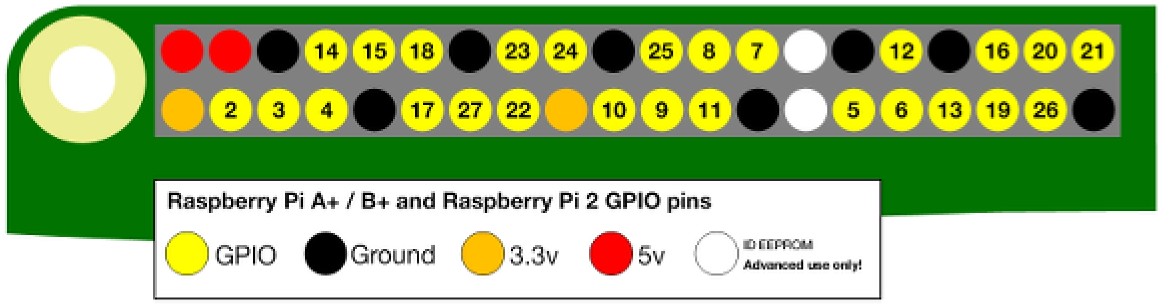


Figure 3: GPIO pins of Raspberry Pi

GPIO Pin Numbering

When programming the GPIO pins there are two different ways to refer to them: GPIO numbering and physical numbering. Throughout this course (and in all our resources) we will refer to the pins using the GPIO numbering scheme. These are the GPIO pins as the computer sees them. The numbers don't make any sense to humans, they jump about all over the place, so there is no easy way to remember them. However, you can use a printed reference or a reference board that fits over the pins to help you out.

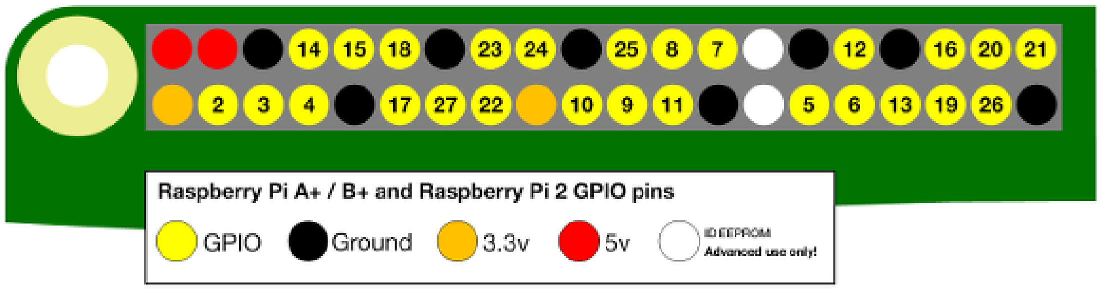

14
15
18
23
24
25
8
7
12
16
20
21
2
3
4
17
27
22
10
9
11
5
6
13
19
26
Raspberry Pi A+ / B+ and Raspberry Pi 2 GPIO pins
GPIO
Ground
3.3v
5v
ID EEPROM Advanced use only!

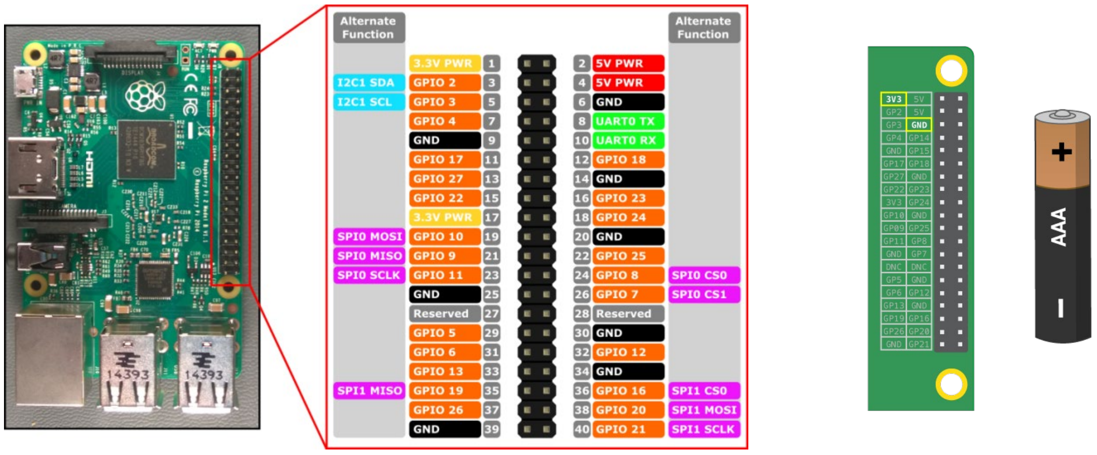
Figure 4: GPIO pins numbering

Building a simple circuit

To build the circuit you just learned about, in this next step, you're going to need your breadboard, an LED, a 330 ohm resistor, and two female-to-male jumper leads.

The first thing to do is to have a look at the GPIO pins on the Raspberry Pi. The two pins we are going to use to begin with are labelled on this diagram. They are called 3V3 and GND.

- 3V3 means 3.3 Volts. You can think of this as the amount of energy that is going to be provided to the circuit. This pin can act a little like the positive side of a standard battery.
- GND means Ground. For a circuit to be complete, electric current must always be able to flow to a ground pin. This is a little bit like the negative side of a standard battery.



Alternate Function					Alternate Function
	3.3V PWR	1	2	5V PWR	
I2C1 SDA	GPIO 2	3	4	5V PWR	
I2C1 SCL	GPIO 3	5	6	GND	
	GPIO 4	7	8	UART0 TX	
	GND	9	10	UART0 RX	
	GPIO 17	11	12	GPIO 18	
	GPIO 27	13	14	GND	
	GPIO 22	15	16	GPIO 23	
	3.3V PWR	17	18	GPIO 24	
SPI0 MOSI	GPIO 10	19	20	GND	
SPI0 MISO	GPIO 9	21	22	GPIO 25	
SPI0 SCLK	GPIO 11	23	24	GPIO 8	SPI0 CS0
	GND	25	26	GPIO 7	SPI0 CS1
	Reserved	27	28	Reserved	
	GPIO 5	29	30	GND	
	GPIO 6	31	32	GPIO 12	
	GPIO 13	33	34	GND	
SPI1 MISO	GPIO 19	35	36	GPIO 16	SPI1 CS0
	GPIO 26	37	38	GPIO 20	SPI1 MOSI
	GND	39	40	GPIO 21	SPI1 SCLK

Figure 5: Details of GPIO Pins at Raspberry Pi

- Take one of your female-to-male header leads and connect the female end of it to the 3V3 pin on the Raspberry Pi.
- Next plug the male end into your breadboard in row 1.

As you can see in the picture below, if you were to remove the back of a breadboard, you would see that every hole of each row is connected by a small strip of metal, that acts just like wires of a circuit.

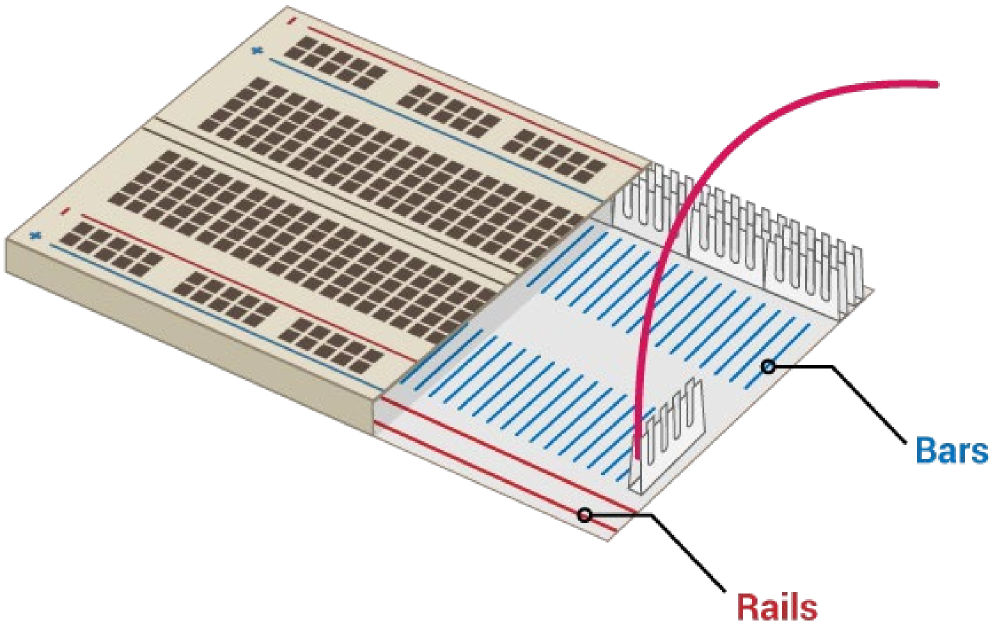


Figure 6: Breadboard

Now have a good look at your LED. This is not a symmetrical component. You should see that one leg is longer than the other. The long leg is sometimes called the **anode**, and this leg should always be connected to the positive side of a circuit. One way to remember this is to imagine the longer leg as having had something added and the shorter leg has had something taken away. Sometimes the LEDs might have legs the same length, in which case you can tell which side is the anode because the plastic rim of the LED will be round, whereas the negative side (called the **cathode**) is slightly flattened.

- Push the long leg of the LED into row one, close to the ravine. Place the shorter leg into row one on the other side of the ravine.
- Now find your resistor. A resistor is a non-polarised component, so it doesn't matter which way around it goes. Push one leg into the same row as the shorter of the LED legs, so it connects to the LED, and the other leg into any other free row.
- Now take another female-to-male header lead and push the male end into the same row as the resistor's second leg. Your circuit should look a little like this:

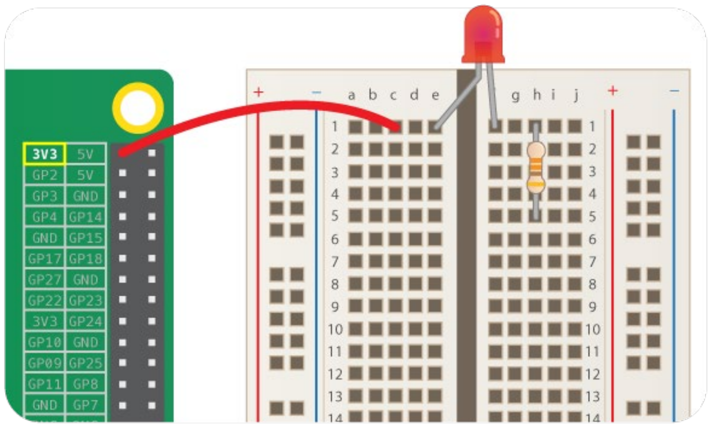


Figure 7 : LED connected directly to 3.3V

- The last step is to connect your components to the ground pin. Make sure that your Raspberry Pi is powered on and then take the female end of the jumper lead and plug it into your ground pin.

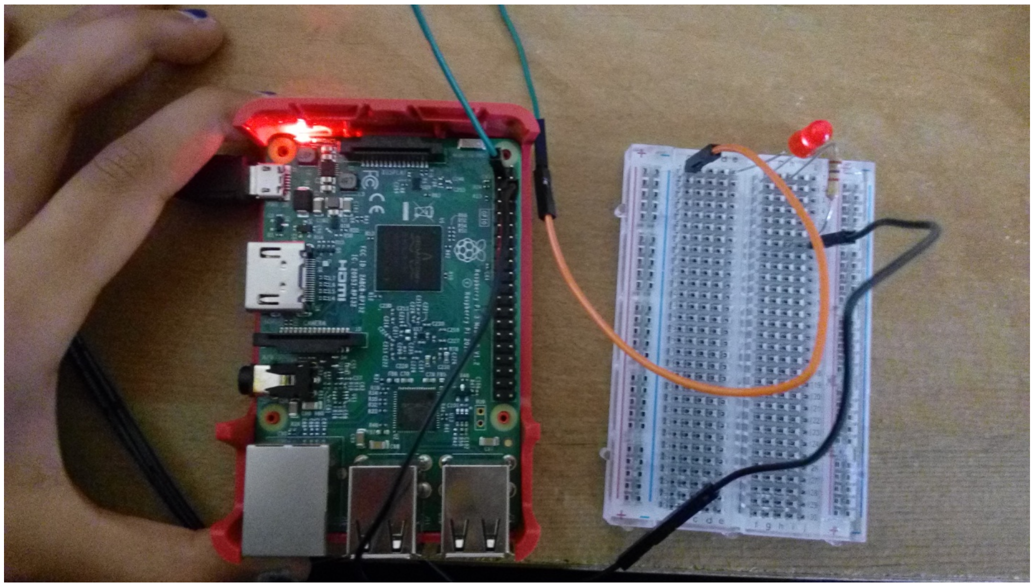


Figure 8: LED Circuit with 3.3 V and Ground

- If your LED doesn't light up, then try the following things:
  1. Check your Raspberry Pi is on.
  2. Check all your components are firmly in the breadboard.
  3. Check your LED is the right way around.
  4. Try another LED.
- You're introducing another layer of complexity and another area where things could go wrong. By testing you know that your LED works and if you encounter problems later you should be able to eliminate the LED as the cause.

Raspberry Pi could act like both the cell and the switch, but your circuit the pin we're using (3.3V) is always on, but other pins can be switched on and off. By making a subtle change to you circuit and writing some code you can control the behaviour of your LED.

The first thing to do is to remove the female-to-male jumper lead from the 3V3 pin. This pin provides 3.3 Volts, no matter what, and can't be controlled. There are plenty of GPIO pins on the Raspberry Pi that can be controlled however, and for the purposes of this exercise, we're going to use pin 17. Connect the female-to-male jumper lead to GP17, as shown in the diagram.

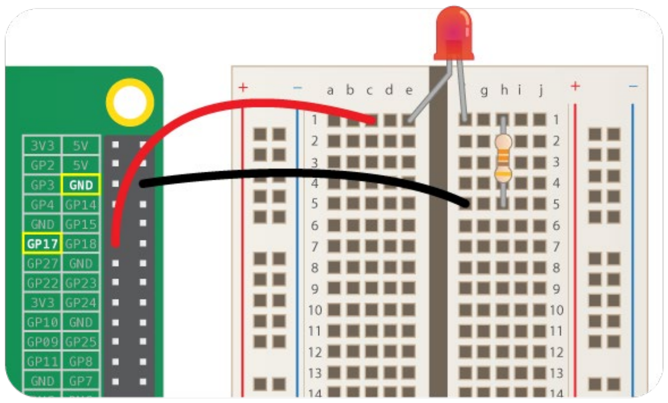


Figure 9: Controlling LED from GPIO Pin

If all is going well then your LED will have turned off. This is because at the moment, pin 17 is in an *off* or *low* state. To turn on the LED, we'll need to set pin 17 to be *on* or *high*. When the pin is in a *high* state, it will provide 3.3 Volts to the circuit. To change the state of the pin, you're going to need a few lines of Python code, which you'll do in the next step.

Blinky blinky lights

We're going to use the *IDE* - Thonny, to write and run the code. Open Thonny by clicking on Menu > Programming > Thonny Python IDE on your Raspberry Pi.

Save this straight away (Save) and call it blink.py.

We used the time module to help write a simple program, and you imported the sleep function. Now we are going to use a module called gpiozero. This module gives you access to the GPIO pins on the Raspberry Pi. You don't need to use the whole of gpiozero in your program, but only a small unit of code called a **class** from the module that helps you control LEDs.

At the top of your file write:

from gpiozero **import** LED

The next step is to create a new **object** for the specific component and pin we are using. Here we've called the object red_led, but the name you give it doesn't really matter. This object can then receive different commands to control it's behaviour.

red_led **=** LED(17)

Save and run your program. You can do this by clicking on Save and then Run Module, or by using the shortcut keys - ctrl + s and then F5.

Nothing will happen right away. Click into the shell (the bottom window in Thonny) and you can now pass some different commands to your red_led object. Try the following two commands.

```
>>> red_led.on()

>>> red_led.off()
```

Your led should turn on and off each time your type the lines. Let's try and automate that a little. Back in the blink.py file you can import the time module, and specifically the sleep function. Alter you code so it looks like this:

```
from gpiozero import LED
from time import sleep
red_led = LED(17)
```

Now you can instruct your program to repeatedly turn the LED on and off again, by using an infinite loop.

```
while True:

        red_led.on()
        sleep(1)
        red_led.off()
        sleep(1)
```

Save and run your program, and see what happens. What does changing the amount of time passed to the sleep function do? What's the smallest sleep time you can use?

A little bit of abstraction

The gpiozero module has some built in methods to give you even more control of your LED. These are abstractions. Complexity has been hidden away, making your code easier to write and more readable.

Either remove your while True: loop or copy and paste your code into a new file so that it looks like this:

```
from gpiozero import LED
from time import sleep
red_led = LED(17)
```

Now you can try adding the following function calls to your program. Try them **one at a time** and play with the numbers to see what they do.

```
red_led.blink(0.1, 0.2)
```

Use your observation to find out the purpose of both values in argument of the function? May be trying different (slightly bigger) values for these arguments will help.

```
red_led.blink(0.2, 0.1, 5)
```

What is the purpose of third argument?

What happens with the following code?

```
red_led.toggle()
sleep(1)
print(red_led.is_lit)
red_led.toggle()
sleep(1)
print(red_led.is_lit)
```

Applied Activity : Lights, sequences and coded messages

Now that you can control a single LED with code there's loads you could do. **First play with** some of the capabilities of the GPIO Zero library at following link:

https://gpiozero.readthedocs.io/en/stable/recipes.html

Here are a few ideas of extra challenges you can set for yourself:

1. Experiment with the frequency of the LED flashes, what's the fastest you can make it flash? Can you make it flash randomly?

2. Can you create short (dot) flashes and long (dash) flashes, giving you the basics of Morse code, with this can you broadcast a message?

3. Can you add extra LEDs to your breadboard and control them with other GPIO pins?

4. With multiple LEDs could you create a simple light sequence in code, this could be something functional like a traffic light sequence or something fun like some blinky disco lights.

Codes for accessing General Purpose input output pins of Raspberry Pi

http://gpiozero.readthedocs.io/en/stable/index.html

Acknowledgement:

The lab is developed using the material available on the internet by James Robinson of the Raspberry Pi Foundation.