1 Introduction

We are going to calculate how much acceleration a skydiver experiences as they fall to earth. We are going to measure the **acceleration due to gravity** or "g". We can use this to derive a figure for the mass of our planet. We can get a figure for the acceleration due to gravity by using a Raspberry Pi to measure the length of time it takes objects to fall through a known distance.

Figure 1: Babbage- the Raspberry Pi bear about to skydive from the edge of space. Copyright Dave Akerman 2013

Here is some background reading, feel free to ignore it and cut to the chase on the wiring diagrams.

2 Electromagnets

When a electrons flow through a conductor, they cause a magnetic field to be created. An electron flow is known as a **current**. When the electrons stop flowing the magnetic field disappears. If we loop the wire into coils, we can create an **electromagnet**, which only operates when the current is flowing. An iron core can be placed in the middle of the loop of wires. This concentrates the magnetic field, making it even more powerful. The more loops we can wrap around the iron core, the more powerful the electromagnet.

2.1 Uses of Electromagnets

Electromagnets are used in Recycling centres to sort the Iron from other metals. The relationship between magnetic fields and electric currents can be used in two different ways - we can generate motion from a current (motor) or generate a current from motion (dynamo/generator).

Incredibly powerful Electromagnets can be made, such as those found in MRI scanners [2]. These are so powerful, they can "spin" protons inside the atoms in your body! Looking at how the spin changes as the magnetic field is changed allows doctors and clinicians to image all parts of your body without the need for surgery or X-rays.

Figure 2: Philips MRI in Sahlgrenska Universitetsjukhuset, Gothenburg, Sweden. Copyright: Jan Ainali 2008

Electromagnets are also incredibly useful to steer charged particles (ions, protons, electrons or more exotic particles). Daresbury use very large electromagnets in their Synchotron radiation source, as do scientists and engineers working at CERN in France/Switzerland. The magnets at CERN generate powerful 8.4 tesla fields - 100,000 times more powerful than the Earths magnetic field.

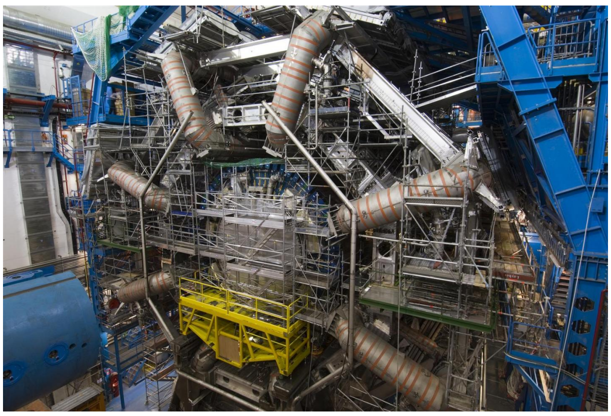

Figure 3: The magnet system on the ATLAS detector includes eight huge superconducting magnets (grey tubes) arranged in a torus (hoop) around the Large Hadron Collider beam pipe (Image: CERN)

2.2 Making an Electromagnet

To make the electromagnet, hammer an iron nail into a piece of wood. Wrap insulated thin copper wire around the iron nail with all loops in the same direction (clockwise or anticlockwise, but not both). Attaching to a 1.5V battery. For this experiment a size D cell (battery) will be used as these provide plenty of current over a long duration.

If we want to control the electromagnet we need to be able to switch on and off the current flowing through the electromagnet. To do this we use a Relay. We attach they relay to interrupt the circuit.

When the current is flowing through the circuit (relay closed), a ball bearing can be attached to the electromagnet. See Figure 4

Q: A relay has a Normally Open connection and a Normally Closed connection. We are going to use the Normally Open connection which will mean the Electromagnet will only work when the Relay is on. What would happen if the electromagnet was wired to the Normally closed side of the Relay?

3 Gravity and Equations of motion

When an object falls to the ground, it's speed increases over time. It is said to **accelerates** due to **gravity**. See 5

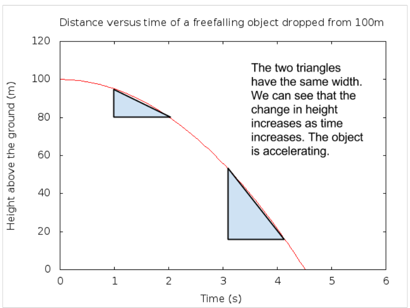

Figure 5: Distance time graph for an object in freefall

In our experiment, we need an equation which describes the gradient of [6]. Luckily, this is all hidden in the Python script on the Raspberry Pi and you don't need to know it. All we need to know is how high the trip switch is from the ball bearing and how long the ball bearing takes to fall. Easy as Pi. If you want to know the gorey details, read the comments in the Python script.

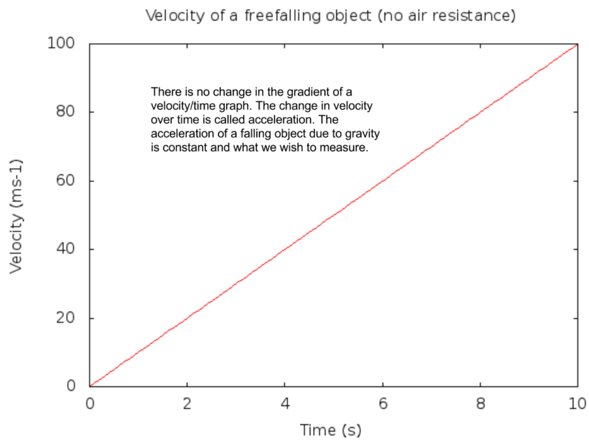

Figure 6: Velocity time diagram for an object in freefall

4 Raspberry PiFace

PiFace Digital plugs into the GPIO (General Purpose Input Output pins) of your Raspberry Pi, allowing you to sense and control the real world.

With PiFace Digital you can detect the state of a switch, for example from a door sensor, a pressure pad or any number of other switch types. Once this state has been detected, the Raspberry Pi can determine how to respond to that switch state. You can drive outputs to power motors, actuators, LEDs (Light Emitting Diodes).

In our case, the Raspberry Pi is going to send a command to the PiFace to switch on/off an Electromagnet. The Raspberry Pi is also going to look for a switch being closed when the ball bearing lands.

There are two methods of detecting when the ball bearing lands:

- Getting a person to push a switch when they see the ball bearing land.
- Building a pressure plate switch which will close when the ball bearing presses the plates together.

Which method is better? Why?

4.1 Building a pressure plate switch

Cut one A4 piece of tinfoil and sellotape the copper ends of the wire to it so that it makes a good electrical contact. Place the cardboard frame on top. Lay a second A4 piece of tinfoil with a wire taped to it on top of the cardboard frame. Sellotape the sandwich together, **but not too tight** - you will need to be

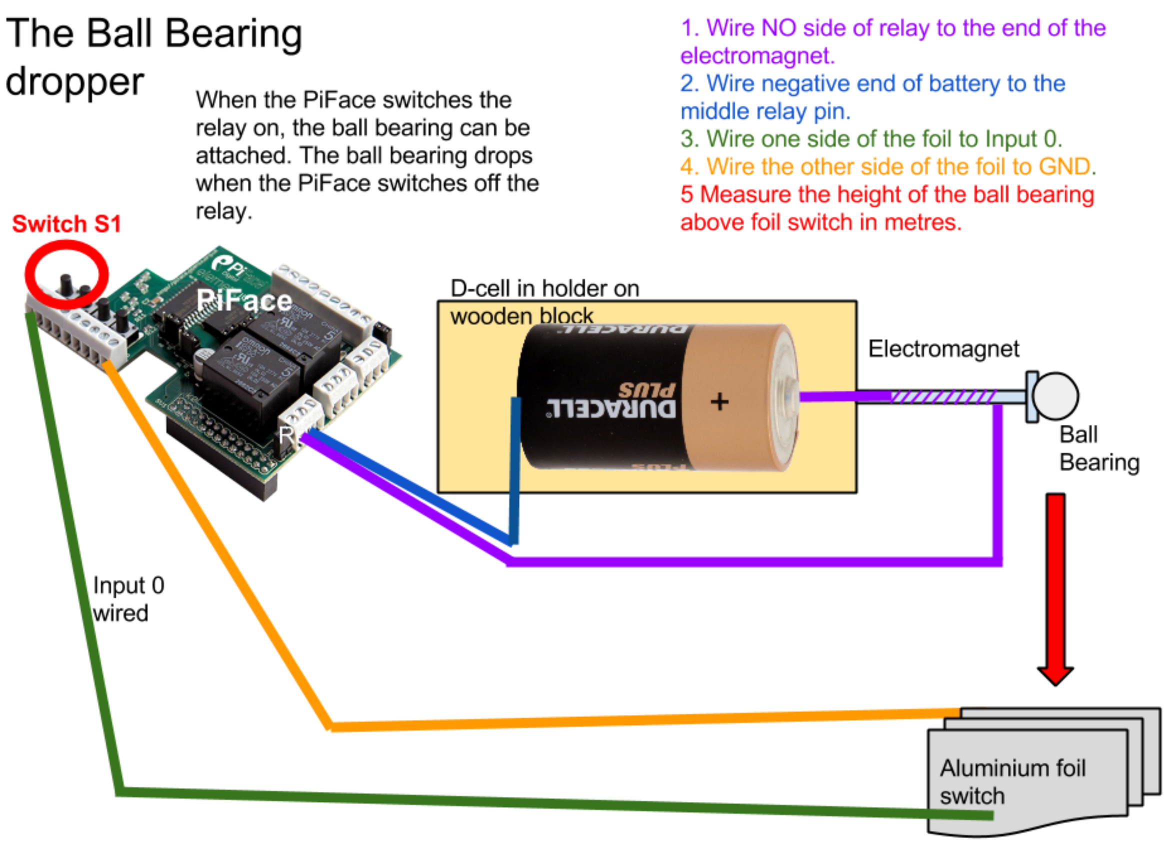

Figure 4: Electromagnet wiring diagram for the PiFace.

able to separate the sheets after they have closed together. The top layer should have a small amount of bounce in it so that when the ball bearing hits it, it can land on the bottom layer.

5 Python programming

5.1 Editing and running a Python program

We are going to edit and run our Python programs using IDLE. Double click on the IDLE Icon on your desktop See figure ??.

Open the gravity.py file using File→Open→Desktop→Gravity→gravity.py. See figure 8

At this point, it is a good idea to review the code before running it to check that it works as planned.

Edit the height *variable* at the top of the program. A variable is a value in a computer program which can change. In this case it will not change, but it needs defining clearly. See figure 9 for where the line **height = 0.70** is. Edit this to the appropriate height for your apparatus.

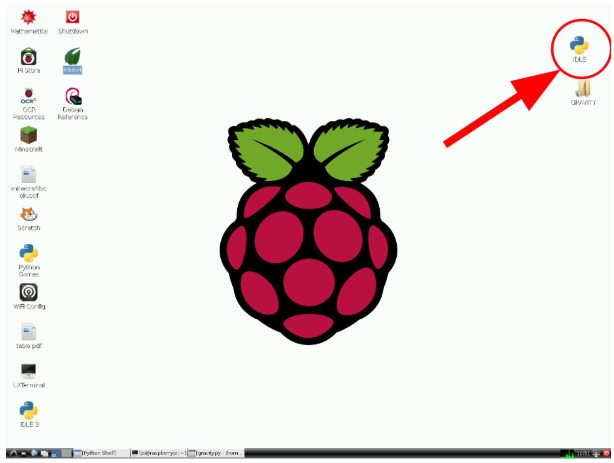

Figure 7: Starting the Python Interactive Development Environment (IDE)

5.2 Running a Python program

Using the top menu, click on Run− >Run Module. See figure 9.

5.3 Code available

Code and documentation are Freely available under the GPL licence:

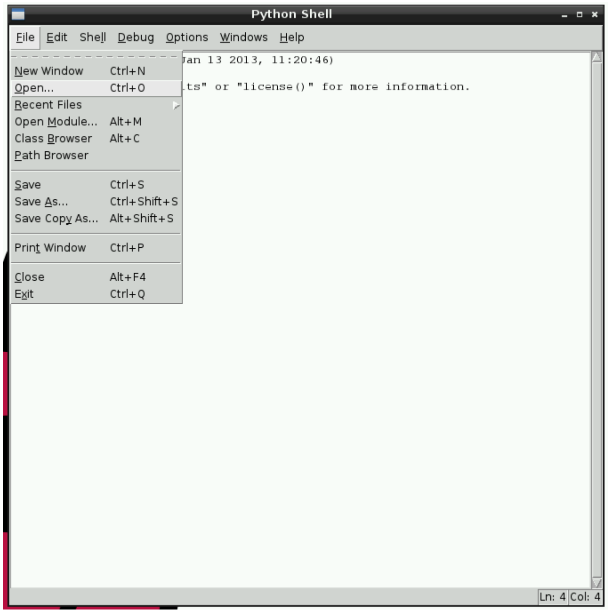

Figure 8: Opening the Python Interactive Development Environment (IDE)

https://github.com/tommybobbins/PiFaceGravityExperiment

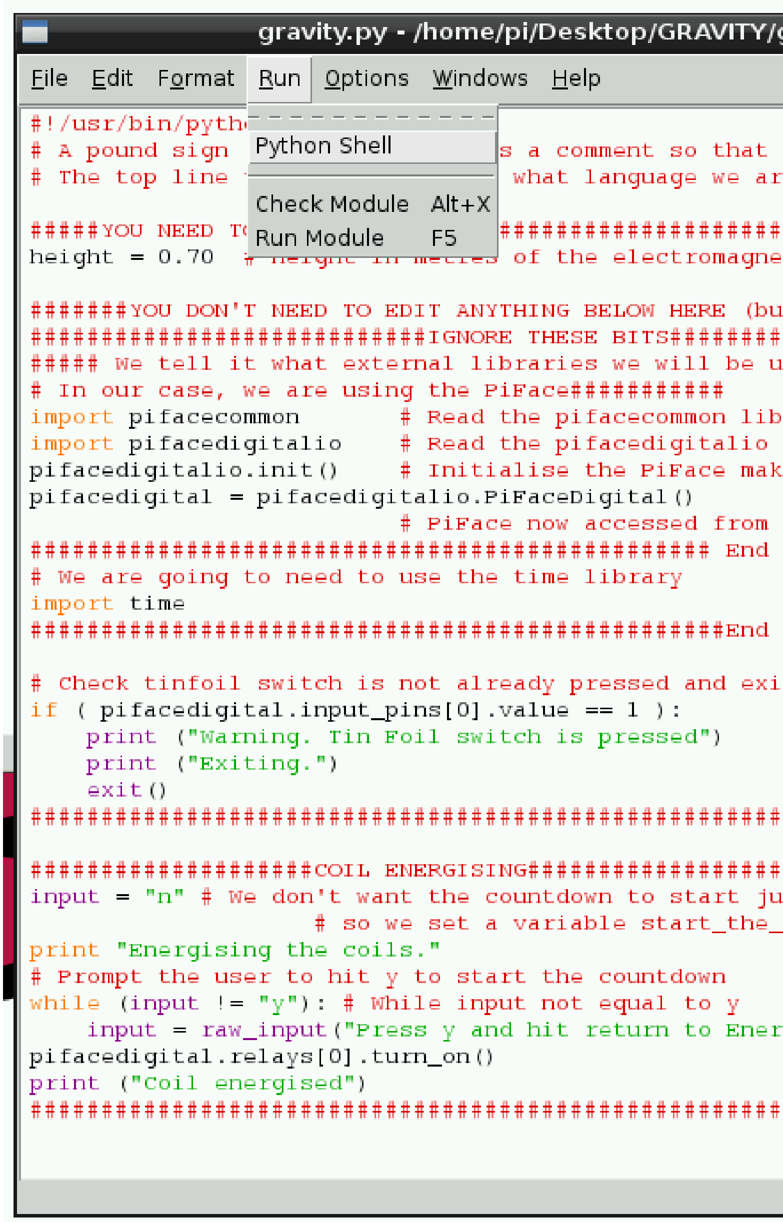

Figure 9: Opening the Python Interactive Development Environment (IDE)