Coupled pendula

A mechanics experiment

Operating instructions

Never Stand Still | Science | School of Physics

Contents

1 Safety

1.1 Personal safety

Some of the equipment is heavy and awkward to handle. Ask someone to help you if you are struggling.

When screwing in the orange masses ensure your body parts are not under the mass in case it is dropped. It will end it pain otherwise.

1.2 Responsible equipment use

When setting up the experiment, make sure you place the pendula on the bench. They are top-heavy and it is easy for them to “dropped” onto the benches.

Be careful not to drop the masses on the ground.

2 Operating instructions

You will be setting up measurement equipment and using customized software. Below are instructions for setting up the measurement, as well as using the software for measurement and signal analysis.

2.1 Measurement set up

The coupled pendulum measurement set-up converts the amplitude/phase data from the pendula into a voltage signal. The voltage signal data is then transmitted to a computer.

Thus, setting up the coupled pendulum experiment involves three key steps:

1. Set up the mechanical experiment (pendula).
2. Set-up the electrical connections.

Figure 1 is a photo of the coupled pendulum set-up with the electrical connections. Key components of the coupled pendulum experiment are highlighted. Figure 2 to 6 highlight some of the features in Figure 1.

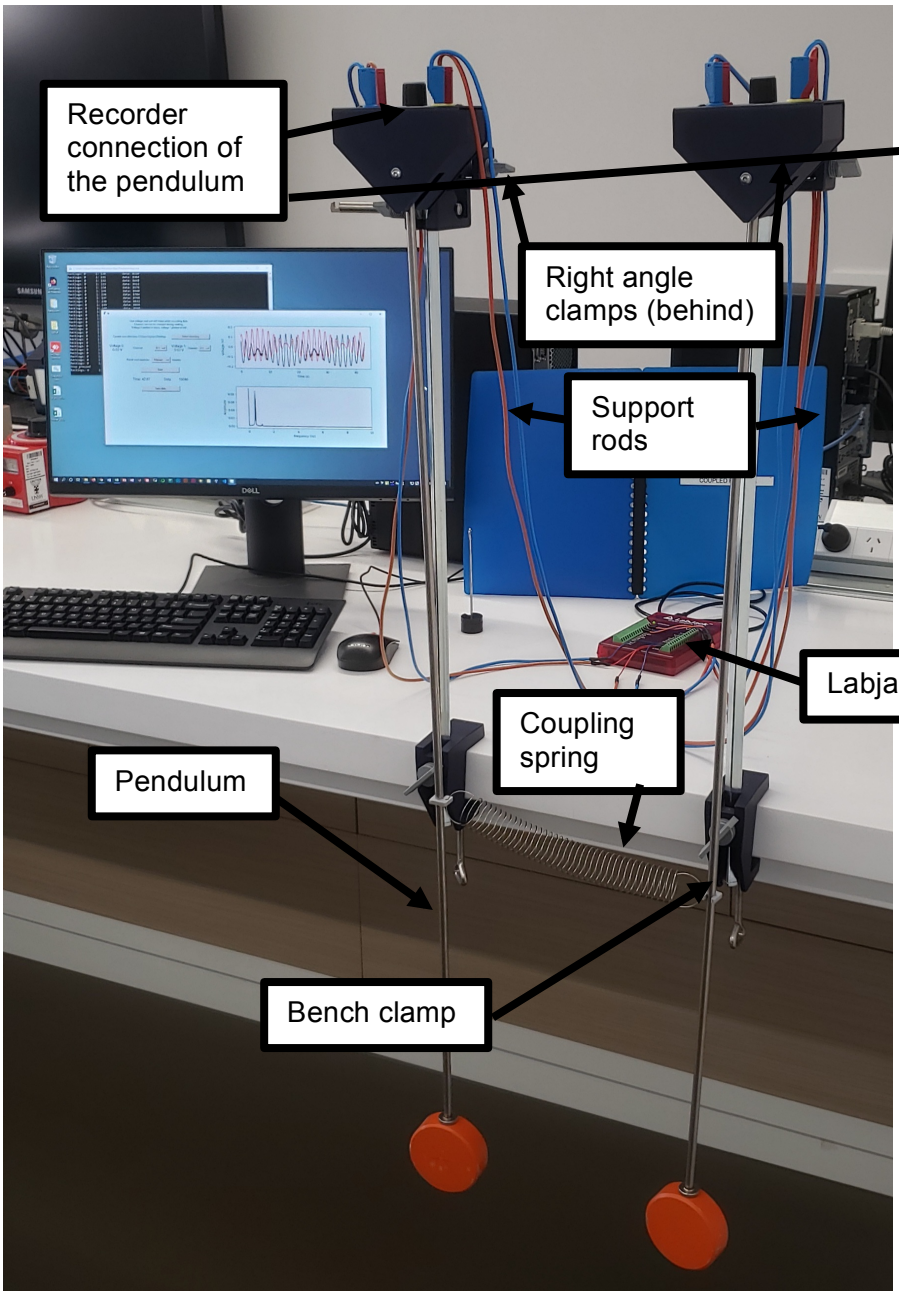

Figure 1. The coupled pendulum set-up.

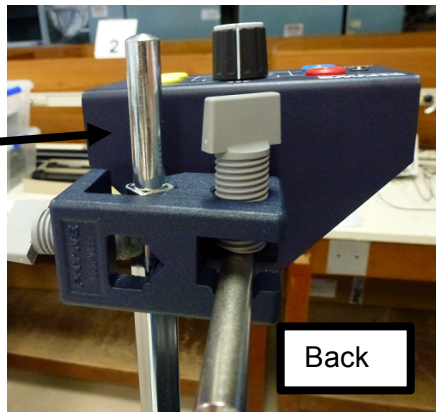

Figure 2. Right angle clamp with pendulum attached.

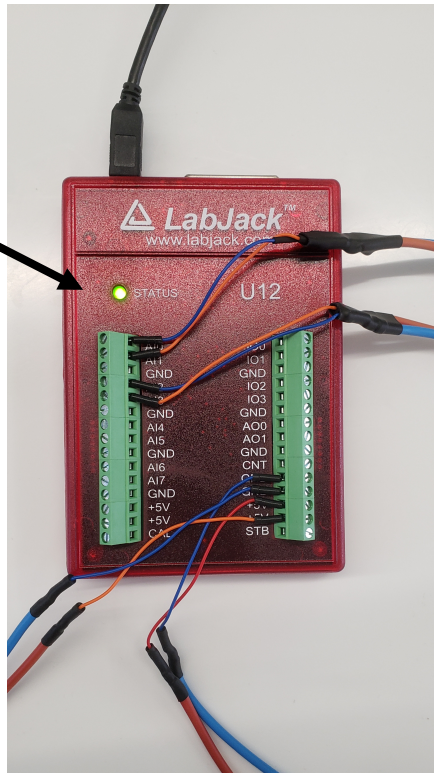

Figure 3. The LabJack, this device acts as both the voltmeter and the DC power supply.

2.1.1 Mechanical set-up

You will set up two pendula. Instructions are given below for only one.

1. Clamp the bench clamp to the table. Ensure it is stable.
2. Attach the support rod to the clamp and tighten. The support rod has a square cross section and is 1000 mm long.
3. Attach the right angle clamp to the top of the support rod. This will support the pendulum.
4. Attach the pendulum to the right angle clamp. The pendulum is the entire unit highlighted in green in Figure 1. The orange weight is detachable and can be rotated to change the length of the pendulum. Use the small nut to hold the orange weights in place. Figure 2 is a picture of the back of the recorder connection which is supported by the right angle clamp. Ensure when the pendulum swings the orange weights don't hit the bench clamp. Check the pendula oscillate in the same plane.
5. To connect the pendula via the spring, use the plastic connection points, as shown in Figure 6. The plastic connection points electrically isolate the spring from each of the pendula. Can you think why this would be?
6. Practice a few times starting the oscillating pendula. It is difficult to get them perfectly in and out of phase. It may help to place fingertips on the side of the pendulum and "push" gently.

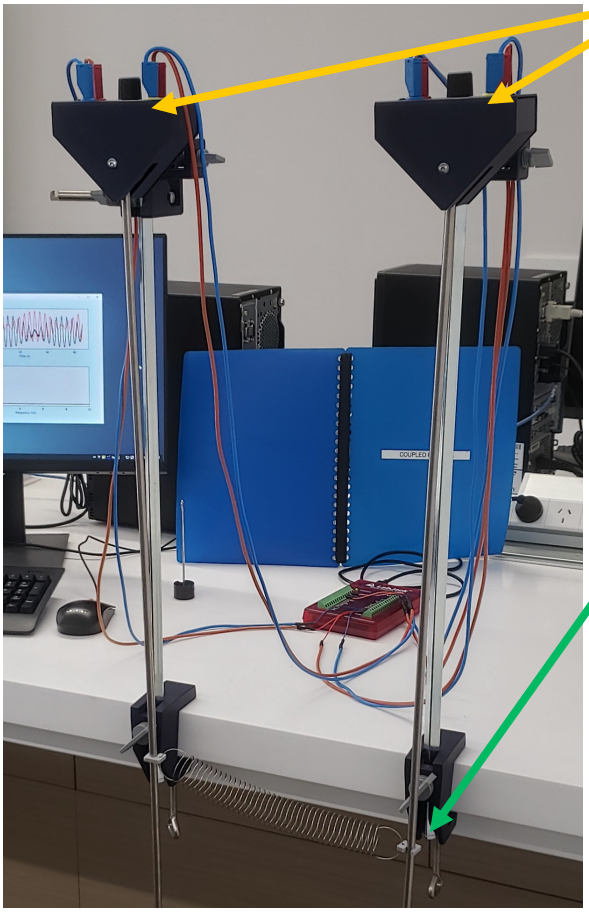

Figure 4. Coupled pendulum set-up with more detail.

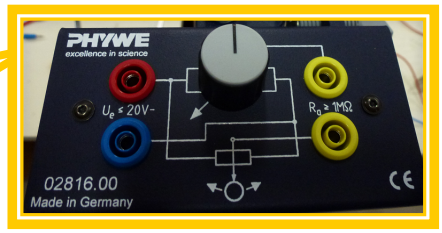

Figure 5. Connections on top of the pendulum recorder connection.

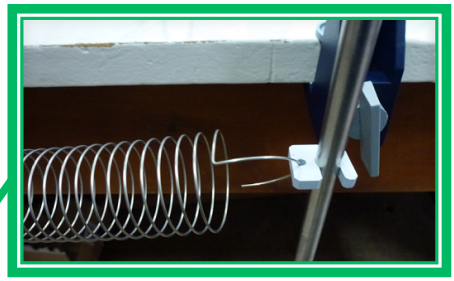

Figure 6. How the spring is connected to, while remaining electrically isolated from, the pendulum.

2.1.2 Electrical set-up

The details of the electrical set up should be worked out in your pre-lab.

The block diagram for the electrical set up is given in Figure 7.

1 µF capacitors are already included in each of the cables that are connected to the analog input ports.

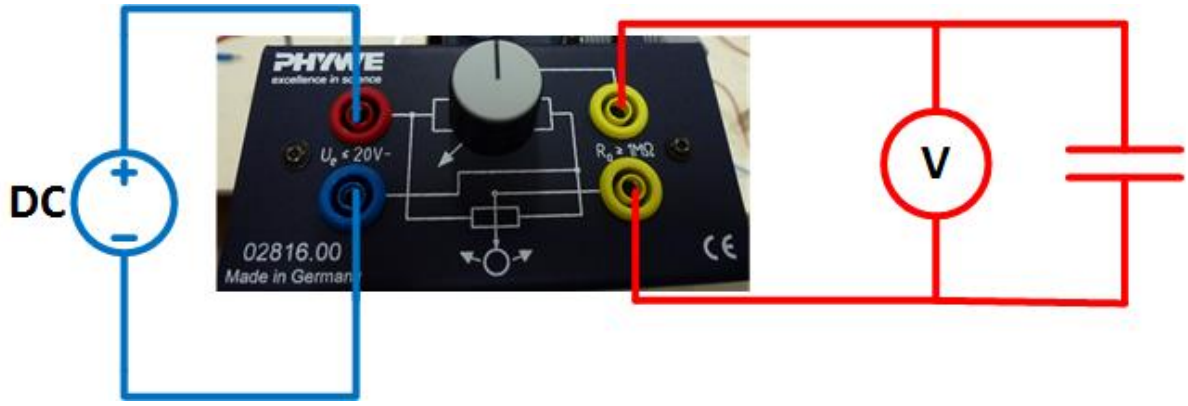

Figure 7. Block diagram for the electrical set up. The blue wires supply a voltage to the recorder connection of the pendulum. The red wires set up the voltage sensing measurement.

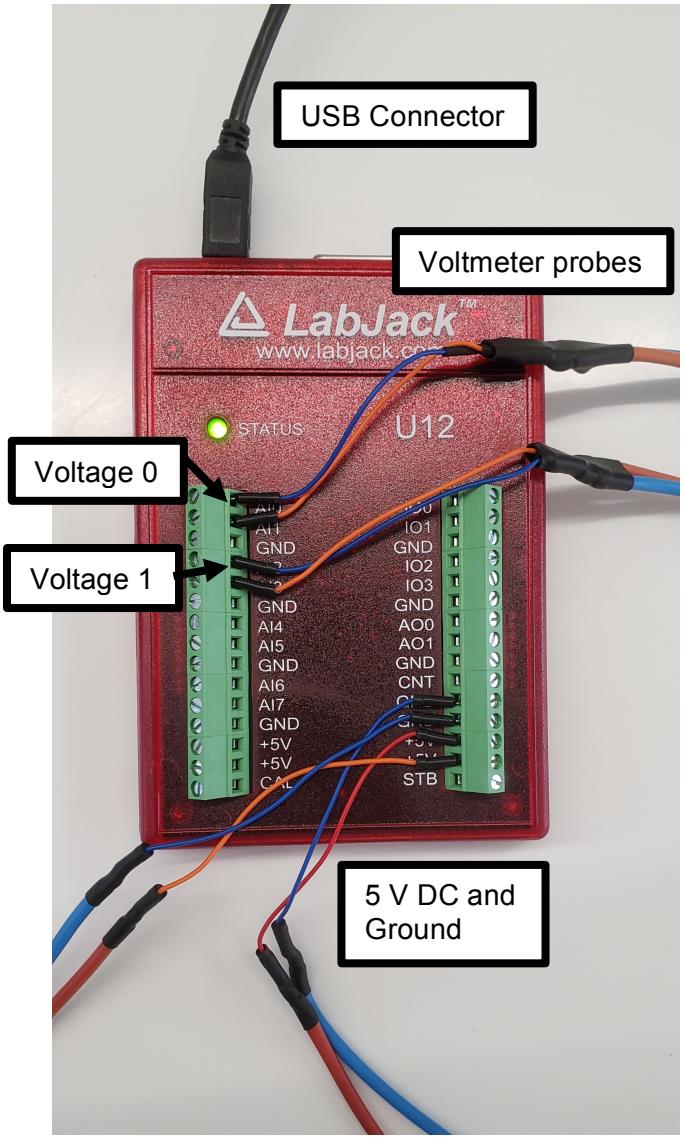

Figure 8. The LabJack with labelled connections

The LabJack is a USB device that can read voltages and output a constant 5 V DC to power the pendula.

As a voltmeter the LabJack can read voltages two different ways:

Single ended: Where it reads a voltage from one analog input (AI) and compares it to ground

Double ended: Where it reads from two separate analog inputs and compares (subtracts) them to each other.

This experiment will use the double ended method as it allows the LabJack to read voltages at higher precision. This means that each pendulum will be connected to a pair of analog inputs (AI0 and AI1, AI2 and AI3).

Each pendulum also requires a connection to 5 V DC power and ground (+5V and GND), both of which are also provided by the LabJack.

2.2 Software operating instructions

1. Connect the LabJack USB to the computer.

2. Find the folder on the Desktop called “PendulumApp”

3. Find the executable PendulumApp.exe.

zope	25/01/2022 1:54 PM	File folder	
zope.event-4.5.0-py3.9.egg-info	25/01/2022 1:54 PM	File folder	
zope.interface-5.4.0.dist-info	25/01/2022 1:54 PM	File folder	
openssl.exe	3/09/2021 12:32 AM	Application	531 KB
PendulumApp.exe	25/01/2022 1:53 PM	Application	16,278 KB
sqlite3.exe	24/06/2021 3:50 AM	Application	1,713 KB
api-ms-win-core-console-l1-1-0.dll	25/01/2022 1:53 PM	Application extens...	19 KB
api-ms-win-core-datetime-l1-1-0.dll	25/01/2022 1:53 PM	Application extens...	19 KB
api-ms-win-core-debug-l1-1-0.dll	25/01/2022 1:53 PM	Application extens...	19 KB
api-ms-win-core-errorhandling-l1-1-0.dll	25/01/2022 1:53 PM	Application extens...	19 KB

4. Open PendulumApp.exe, it will open a black terminal, then shortly after the application as shown in Figure 9 bellow will appear.

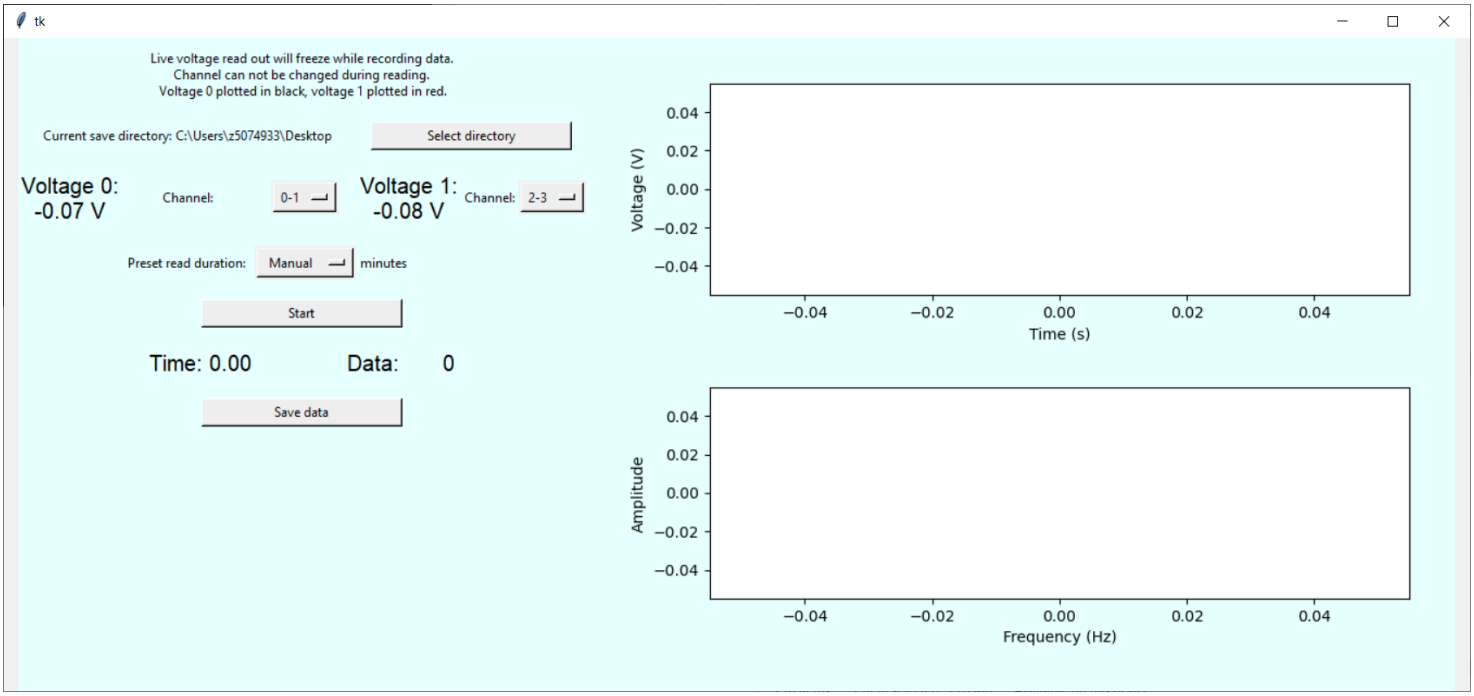

Figure 9. Software when first opened

Once open, if everything is working correctly the voltages under Voltage 0 and Voltage 1 should change if the pendula are moved. By default, the software will be set up to read AI0 & AI1 and AI2 & AI3 each in double ended mode as shown in the channel dropdown; If working these menus should be left as is.

Before reading data, the pendula need to be calibrated. TO do so make sure the pendula are perfectly still, then adjust the resistir knobs on the top of the pendula until the current voltage reading is as close to zero as possible.

To aquire data, the user can either press start then stop once enough data is recorded or they can use the preset read duration drop down to pick some number of minutes they would wlike to record for.

Once recording is done, the user must press save data, this will save two files to the current save directory.

The first is the time series data which contains the voltages of both pendula and the time (cp_YYYY-MM-DD_HH-MM-SS.csv)

The second is the fourier transform of voltage 0, which includes the amplitude and frequency (fourier_YYYY-MM-DD_HH-MM-SS.csv)

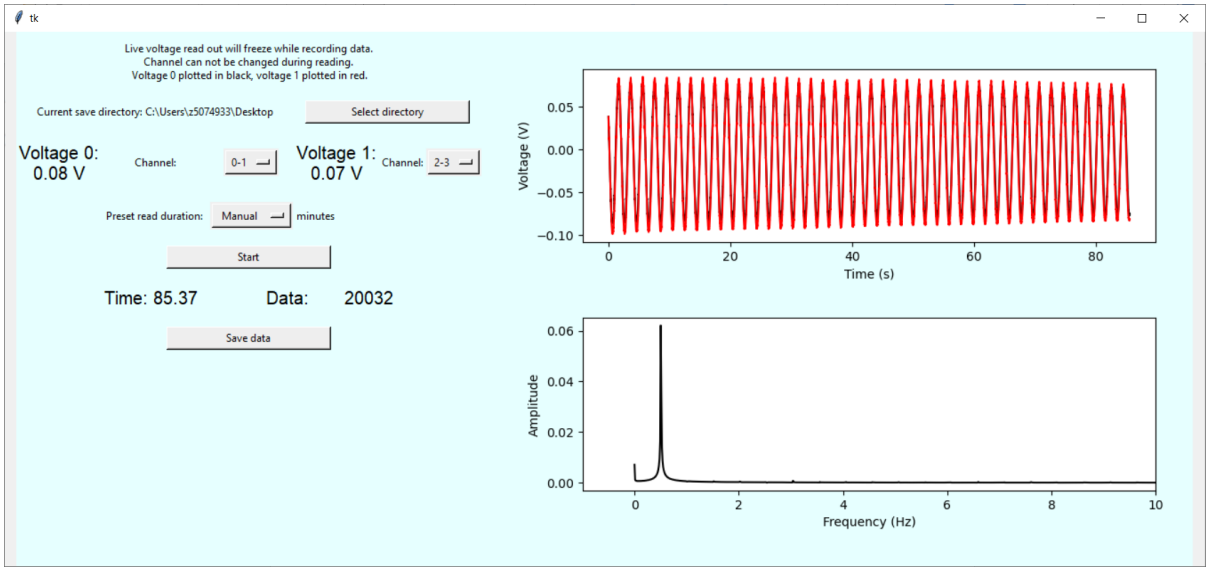

Figure 10. Example of the software after acquiring data