Experiment 1

Introduction to use of iOLab and software, and perform an experiment of your own choice.

In order to efficiently carry out later experiments the following learning goals are important:

You will be able to

- turn the iOLab on and off.
- connect iOLab with the software.
- make measurements with iOLab's wheel sensor, accelerometer and force sensor.
- calibrate sensors.
- read off data points (time and measurement value).
- zoom on a graph of measurements.
- rezero force sensor.
- smooth measurement data.
- determine average and uncertainty on a measured quantity in an interval.
- perform linear regression on a measured quantity in an interval.
- determine the area under a curve on a measured quantity in an interval.
- plan, describe, and perform a measurement or a measurement series.
- identify sources of error in connection with a measurement.
- write a short lab report on your experiment of choice.

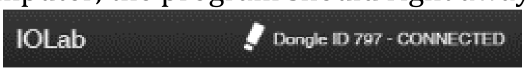
The first experiment creates the foundation for the following mechanics experiments, so you will need to master a number of things when using the iOLab sensors and the software. The lab report should only be about the experiment of choice.

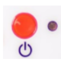
Installation of software

In order to get started you should download the software for iOLab and install it, you can find it on the web page iolab.science. After download, installation and starting the program you can proceed.

Turn on iOLab and connect to the software

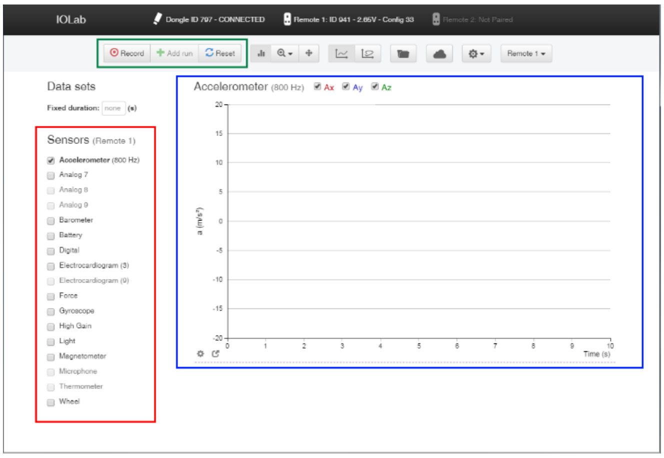
Remove the usb from the iOLab by pressing on the metal part, then the plastic part is pushed out and you should be able to pull out the usb.

Insert the usb in the computer, the program should right away recognize the usb; it should be visible in the top of the program. 

Turn on the iOLab (see button to the right); the diode should light up.  If iOLab is not used for a while it will automatically shut off; if this happens just turn it on again.

Selecting sensor(s)

You should see a picture like the one shown, here you can see that the usb has been recognized and the iOLab is turned on. The three frames (colored red, green, and blue) have been added and are not visible in the software. The red frame contains the sensors that can be chosen, the green frame contains data collections command, and the blue frame contains graphs of the measured data.



Choose the accelerometer in the red frame (it has been chosen in the picture).

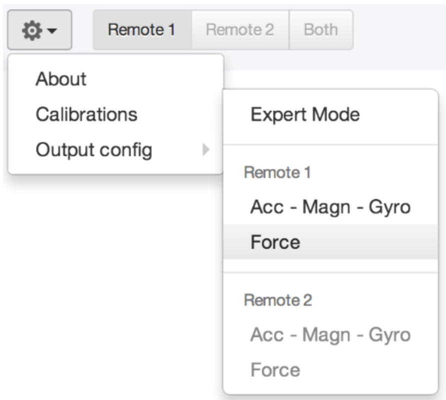
When you (later) make measurements the data will be visible in the blue frame (there may be several graphs shown). Press Record in the green frame, now iOLab collects data from the accelerometer. By moving the iOLab you should observe a signal. Press Stop when you have enough data.

Later you will use several sensors at once, but be aware that not all combinations of sensors are possible.

Calibration of accelerometer and force sensor

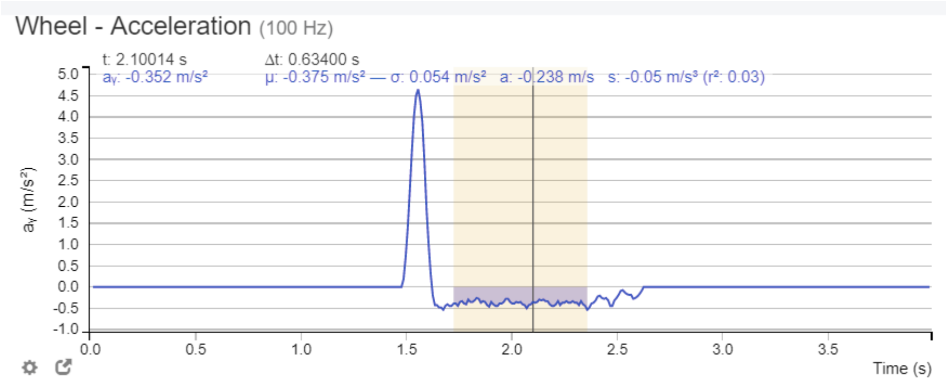
To get the best possible measurements it is important to calibrate some of the built-in sensors. Press twice on Reset 

(the button is in the green frame). Go to the tools menu where you can carry out the calibrations; the first calibrates the accelerometer, the gyroscope, and magnetometer, the second calibrates the force sensor. Follow the instructions on the screen.



Analyzing data

Let us turn to viewing and analyzing data. The image shows a graph of the measurement of acceleration using the wheel sensor.



When the graph icon  is activated the cursor on the computer is used to select areas for inspection and/or analysis. By left clicking and dragging the mouse (or similar device) you can select an area like the yellow area above. For the acceleration data in this selection you can see a number of computed values. The first value (μ) is the average for the quantity in the selection and (σ) is the standard deviation of the same data. If you select only one measurement value in the selection, the standard deviation is the uncertainty on this value. The cursor selection of one single point above has the average $-0.352\ \mathrm{m/s^2}$ with a standard deviation (uncertainty) of $0.054\ \mathrm{m/s^2}$. This measurement value would be reported as $a_y = -0.35 \pm 0.05\ \mathrm{m/s^2}$. If you, however, use the average we need to determine the uncertainty on the average, which is $\frac{0.054\ \mathrm{m/s^2}}{\sqrt{N}}$ where N is the number of selected data points. The number of selected data points can be calculated as $N = f \cdot \Delta t$ i.e. the product of the frequency (100 Hz in this instance, see above) and the length of the selected time interval (here 0.63400 s, can be seen below the frequency). In the example we get $N = 63.4$ and inserted into the formula for the uncertainty of the average yields $\frac{0.054\ \mathrm{m/s^2}}{\sqrt{63.4}} = 0.00678\ \mathrm{m/s^2}$. If we use the average then the measurement reported is $a_y = -0.375 \pm 0.007\ \mathrm{m/s^2}$.

After the information about average and uncertainty there is a value, a, that represents the area under the curve, and finally the quantity, s, that represents the average slope of the graph in the selection (with a regression coefficient in parantheses); the quantities are always computed.

If you select the magnification glass  you can use the mouse to select a rectangular area for zooming. If you double click on the graph the program will zoom out to standard view. When you zoom in on one graph all graphs will change their time axes. If you zoom too much you double click to get back to the standard view.

When you activate the arrows  you can shift the graphs to the right, left, up, and down.

Each time you make measurements the data are automatically saved in the folder Documents/iOLab-WorkFiles/rawdata on your computer. You can always go back an retrieve data for further analysis by clicking on the folder icon . If you need to do additional analyses you can export data in csv format to be imported into, say, Excel. Click on the tool bar symbol in the lower left corner then data are exported to the folder Documents/iOLab-WorkFiles/export on your computer.

A simple measurement

Determine the air pressure where your iOLab is standing. Remember to include units and uncertainty.

Using the wheel sensor

You will now use the sensor called Wheel. It is located in connection with the three wheels on of the sides of iOLab (the measuring wheel is the single wheel). The sensor can be used to study straight line motion and measures position, velocity, and acceleration. You can select one, two or all of these three sensors

(the selection influences what is shown on the screen, but all three quantities are always measured and can be added later if necessary). To use the sensor place the iOLab on the wheels. Note that it is only motion in the y-direction that the sensor measures.

Measurements

1) Make a measurement over, say, 20 centimeters, where you move iOLab with a constant velocity. Use the gathered data to investigate the velocity, and how far you moved the iOLab.
2) Make a measurement where iOLab is moved back and forward a few times. Read the maximum value for position, velocity, and acceleration.
3) Pick a specific time point on the position graph (not at a maximum or a minimum). Use the graph to determine the velocity at this time point. Use the velocity graph to check your value for the velocity against the measured value.
4) Pick a specific time point on the velocity graph (not at a maximum or a minimum) and use the graph to determine the acceleration at this point. Use the acceleration graph to check your value for the acceleration against the measured value.
5) Look at the velocity as a function of time. Select a time interval and determine the integral of the velocity over the interval. What does the integral mean? Check if you are right.
6) Look at the acceleration as a function of time. Select a time interval and determine the integral of the acceleration over the interval. What does the integral mean? Check if you are right.

Uncertainty estimated from single measurements

Mark a distance on the table and measure its length with a ruler or similar. Estimate the uncertainty on the measurement by considering how accurate you can read off the ruler. Now measure the length with iOLabs Wheel sensor. Compare the two measurements. Do they agree within the uncertainty?

Using the force probe

Now you will use the force probe. Note that the force probe should not be subjected to more than 10 N (roughly corresponding to a hanging 1 kg object).

Screw in the eye-bolt in the force probe (but not too tight). Select the force sensor and place iOLab on a table such that the eye-bolt is pointing up. Make a measurement, and determine the force. Is it zero? Rezero the sensor and repeat, is the reading zero now? Determine the force of gravity on an iOLab and the mass of the iOLab.

You will now investigate whether there are systematic errors present when using the force sensor. For the experiment you should screw the eye-bolt into the force probe. Make ten measurements where you measure the force of gravity on masses 20 g, 40 g, 60 g,…, 200 g and note the force of gravity for each measurement. For each measurement you should also calculate the corresponding mass. The hook with bottom disc has a mass of 20 g, and each of the additional nine discs also have a mass of 20 g. The mass of the hook and discs in the picture is 60 g (one hook and two discs).

Plot the measured mass as a function of the mass.

Are the measurements reliable in all ten measurements? If not, when are they reliable?

Is there a constant absolute deviation? Is there a constant relative deviation?

Experiment of your own choice

Perform one or more experiments involving at least one of the iOLab's sensors.

Write a short lab report of the experiment you have chosen. Make sure that you include hand drawn sketches of your experimental setups (you can take pictures of them).