

# PHYS 1P91 Experiment 01

## Introduction to the iOLab

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### Notes

- Words in [blue](#) are links to additional reading or videos.
- Text in [gray](#) boxes are hints and things to take note of.
- Text in [red](#) boxes are important instructions or prompts that guide you to DISCUSS some of the key RESULTS and CONCEPTS learned in the lab. These prompts may not be the only items that need to be included in your report.

## 1 Lab objectives

- Learn about the iOLab, and how to collect data.
- Learn how to prepare and submit a lab report.
- Introduction to measurement uncertainty and precision.

## 2 Introduction

The iOLab is a lab-in-a-box, and contains many sensors that can measure many aspects of the physical world around it. You will be using some of these sensors to learn more about [kinematics](#), which is the study of motion of objects. You probably think you have a good intuition about how things move, but we find that these preconceptions are not always right! Hopefully in this course you will improve your problem solving skills while unlocking the secrets of how baseballs fly through the air and how planets all orbit the sun.

Hopefully you will also improve your digital skills as you collect, analyse, store, and present a lot of digital data. In this lab we will use a few sensors that are not directly related to kinematics, just to explore what the iOLab can do. You never know when inspiration might strike, and you want to measure something for another class with the iOLab!

## 3 Procedure

Throughout each lab, we will try to help guide the experiment with hints, diagrams, and videos. Even so, much of the success of the lab rests with you! So use the procedures of this first experiment to learn more about how the iOLab functions.

A series of general introductory videos to the use of iOLab can be found on Sakai under [Lab Resources](#). (Links to videos require logging into Sakai.)

Labs are asynchronous, but there will be times that you need help. You can attend the online live lab help during your registered session, or any of the other available help sessions through the week. There, you can ask your teaching assistant questions and get helpful hints if you are stuck.

Please come prepared to each session, having tried on your own to collect or analyze the data from that week's lab! There will not be any demonstration of the experiment start-to-finish.

As deadlines are standardized for the entire class, do not wait until the last minute to ask for help. Just because you registered for a Friday lab does not mean you can't start the lab as soon as it's posted and get help early in the week.

In lab sessions, you may want to share your desktop screen in the online session with the TA or other instructor, so that they can diagnose any issues you may be having.

Please be aware of any sensitive data like websites or usernames that may be visible, and which you don't want to share with anyone. You may be disconnected if offensive material is shared with the class.

### 3.1 Prepare the iOLab.

Start by reviewing the [unboxing](#) lab resource to learn about what is included in your iOLab kit.

Insert the iOLab USB dongle into your computer and turn on the iOLab. Connect to the iOLab online software following the directions provided in [setting up the software](#) and [taking data](#).

## 4 Take data

The “Take data” section is where we discuss the experiments you will conduct using the iOLab. Keep in mind that sometimes when you collect a lot of data, plots may take some time to render, or show up on the screen. Be patient and wait until the graph re-plots to show the full data window.

If you have not already done so please download the report template to ensure you record all data, and save all photos required to complete the lab. Even if you do not fill it in as you take data, make sure you know all of the values/images that must be included, as you do not want to finish the lab and realize you missed a graph - it will happen.

### 4.1 A weather report

You are probably indoors right now, but let’s take a ‘weather’ report for wherever you are.

From the list of iOLab sensors, select Thermometer and Barometer. You will note that when you select the thermometer sensor the number “(50)” pops up beside it. For the barometer it’s “(100)”. This is the rate of data that is collected; 50 Hz for the thermometer, and 100 Hz for the barometer. If you collect 2 seconds of data at 50 Hz, you will be collecting

$$n = 2 \text{ sec} \times 50 \text{ Hz} = 2 \text{ sec} \times 50 \frac{1}{\text{sec}} = 100 \quad (1)$$

data points.

Take at least 2 seconds of data.

Download and save your data to a folder on your computer. Save the two data sets separately.

In your lab report, record the length of time you recorded data, and the number of data points that represents.

The exact length of data collection doesn’t matter in this scenario. In principle we could ask the iOLab for a single data point.

Note that the two downloaded files will have the same filename. You will want to rename them to indicate which is the thermometer and which is the

barometer data, or you will forget.

You will notice that the data seems to jump around a lot. But is it really a lot? Look closely at the scale of the y-axis. What is the amount of *variation* in the data, when compared to the *average* value of the data? Just how *accurate* is this data? (These are rhetorical questions, and you don't need to answer them right now.)

Look closely at the numbers found to the right of the graph in iOLab-Online. You will see:

- The number of data points  $n$  that either are plotted or selected appears in round parentheses,  $x(n)$ .
- The minimum and maximum value of the x-axis, in square parentheses,  $[x_{min}, x_{max}]$ .
- The mean, or **average** ( $\bar{y}$ ) of the all the data currently on display in the graph:

$$\bar{y} = \frac{1}{n} \sum_{i=1}^n y_i$$

- The **standard deviation** ( $\sigma_y$ ), or the measure of the variation of the data around the average:

$$\sigma_y = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (\bar{y} - y_i)^2}$$

- The area ( $\int_y$ ) and slope measures we will get to another time.

The standard deviation is the variability in the measurement, and represents your measurement uncertainty. Formally, you would record a measurement of a variable  $y$  as

$$\bar{y} \pm \sigma_y. \tag{2}$$

To learn how to write values this way please see the resource on [significant figures](#)

For these measurements we expect the uncertainty to be much less than 1% of the accurate value. This is a measure of the *precision* with which the iOLab can measure temperature and air pressure. Whether the values you measure are *accurate* depends on the calibration

of the sensors. An interesting introduction to accuracy and precision can be found [here](#).

Properly label and save two graphs, one for the temperature in the room, and one for the barometric pressure. Include them in your lab report.

Record in your lab report the average temperature and barometric pressure of where you are now. Include the uncertainty. Determine what the theoretical value should be, For example record the latest outside temperature and barometric pressure readings for your location from the Environment Canada website, or the meteorological website for wherever you are. If you are in an air-conditioned environment, what is the temperature of the system set to be?

Calculate the percent difference. What percent of the percent uncertainty of the data? (see hint below)

Hint:

**Percent Difference** is how far away your ‘calculated’ value is to the ‘true’ value and can be calculated as:

$$\% \text{ Difference} = \frac{2|A - B|}{(A + B)} 100$$

**Percent Uncertainty** is how large the uncertainty actually is with respect to the true value and can be calculated as

$$100 \times \frac{\sigma_y}{\bar{y}}.$$

## 4.2 How bright is it?

The iOLab also has a light sensor. Select the Ambient Light sensor.

Take about 10 seconds of data, while rotating the iolab, pointing the light sensor at different parts of your room.

Download and save your data to a folder on your computer.

- The exact length of the data collection doesn't matter! Just set it long enough for you to make one full rotation of the iOLab.
- If you are doing this during the day, and have a window nearby, hold the iOLab upright and slowly spin it so that it faces towards and then away from the window.
- If you are doing this at night, turn the room light on. Slowly spin the iOLab so that it faces toward and then away from the light.

**Did your computer get slow to respond?** The Ambient Light sensor gathers data at 4800 Hz, or at 4,800 points per second. Over 10 seconds, this is 48,000 data points. This may be too fast to see real time data collection, and may slow your computer to graph that many points. (Note that the actual number of data points recorded may not *exactly* equal to 48,000, due to the way the iOLab communicates with the computer.)

**One trick to remember** to collect *fewer* data points, but over the same amount of time, is to select the Wheel sensor along with any other sensor.

For example, selecting Wheel with Ambient Light together will lower the data rate of the Ambient Light sensor to 100 Hz, or 48 times fewer data points. If you don't *need* the wheel data, don't worry about it.

Can you see when the iOLab was facing the window or light, and received the highest intensity of light?

Properly label and save a graph of the intensity of light around you. Include it in your lab report.

Why does it not make sense to record the average and standard uncertainty of the ambient light data?

### 4.3 Calibrating the force sensor

Kilograms are a unit of mass, and N, pounds, etc are units of force. Typically in every day life, there aren't many situations when you weigh something and need to differentiate between mass and weight. Due to this, mass and weight end up being used interchangeably since weight is often times proportional to mass. Sadly, we cannot treat things that simply when it comes to physics! The distinction between mass and weight become far more important and one needs to be careful of which they are referring to.

For example, mass (SI units of kg) is an intrinsic property of something. It doesn't change regardless of where you are in the universe, which is extremely useful! Measured weight (SI units of N) on the other hand changes based on a number of factors. Since weight is a force, if an object has other forces acting on it, it is much harder to determine its exact weight. Additionally, depending what planet something is on, it will have more or less weight since gravity is different! More explicitly, in equation: 3, we can see that the weight force is simply mass times gravity.

$$W_F = mg \tag{3}$$

The iOLab has a force sensor; a mechanism that works just like a spring weigh scale that can measure up to 10 N in force pushing or pulling. It's not terribly precise, and like the adjustment on any spring weight scale, it needs to be calibrated. More so, it needs to be calibrated differently depending on if something is pushing or pulling on the iOLab force sensor.

Attach the eye bolt to the force sensor, following the directions in [attaching items to the force sensor](#).

Let's first calibrate the force gauge in the orientation of something hanging from it. Use a paperclip and fashion a holder for the 100 g mass that came with the extra kit. It may look something like Figure 1.

Connect your device to iOLab online. Select ForceGauge, and prepare to take about 3 seconds of data.

First we will set a calibration value when there is **no mass attached**. This will zero the scale. Then we will set the value when the 100 g mass is attached. This ensures we have two points of calibration; one to know where 0 is, and one to know exactly how much force a gram produces so we can scale our data properly. It's ok if this is hard to understand, as



Figure 1: Example holder for the 100 g mass made from a paperclip.

long as you know your tools need to be calibrated before use.

**Important:** Reduce the data rate by selecting the Force Gauge and Wheel sensors for this entire section. We will only use the force data, but selecting both limits the data collection rate. After taking data, *make certain* you are looking at the force data.

**To calibrate the iOLab:**

1. Hold the iOLab upright, with the eye bolt at the bottom, y-axis pointed up. Add the paperclip holder, but not the mass itself!
2. With nothing else touching the eye bolt or hook, take the about 3 seconds of data.
3. Then open the Settings drop-down menu.
4. Click the 'set zero' button.
5. Attach the 100 g mass to its holder, and hold up the iOLab.
6. While the 100 g mass is at rest, take another 3 seconds of data.



7. From the **Settings** menu, select the 'calibrate' button with the value of 100 grams in the text box.

It is good to verify the calibration worked.

1. Still holding the iOLab up, take another 3 seconds of data.
2. When you now click **Draw** (below the data window), the average of the data collected should now be re-centred around a value of  $W = mg = 0.10 \text{ kg} \times 9.81 \text{ m/s}^2$ . If the data is not centred to this average, you will need to re-calibrate.
3. You may now minimize the **Settings** drop-down menu.

Now the **ForceGauge** is calibrated for when things are hanging from it, and the iOLab y-axis is pointed up. The iOLab is now ready for any experiment in this orientation.

Sometimes, we will be measuring force when the iOLab is pointed down, and it is hanging from it's own force sensor. To adjust the calibration we just did we must add one last step:

1. Reopen the **Settings** drop-down menu
2. Remove the mass and holder, but not the eye bolt. Flip over the iOLab, and set it down on a flat surface with the force sensor upwards (y-axis pointed down).
3. Collect 3 seconds of **ForceGauge** AND **Wheel** data.
4. Click the 'set zero' button.
5. You may now minimize the **Settings** drop-down menu.

Now the **ForceGauge** is calibrated for when it is hanging from it's own force sensor, and the iOLab y-axis is pointed down. Later, we will do this step when we use the iOLab on its side.

#### **4.4 What is the mass of the iOLab?**

To measure the mass of the iOLab, it will be hanging from it's own force sensor by the attached eye bolt, so you have to do the last step of calibration above in the upside-down orientation.

Disconnect the mass holder from eye bolt. Set it down on a flat surface, the y-axis pointed down and the force sensor pointed up.

1. Set to record about 15 seconds of Force Gauge and Wheel data.
2. In the first 5 to 7 seconds, let the iOLab sit still on the table.
3. In the last 5 to 7 seconds, lift the iOLab by its eye bolt.

This experiment is to get you to think about how to manage the timing of experiments; when to hit Start, when to take action with the iOLab, and how long the data collection should be to capture everything you need. To correctly analyze your data you will need to review the video on [analyzing data](#).

Record and save the data to your computer.

Select data in the flat region after the iOLab had been lifted and record the mean (average) weight of it. Include the uncertainty. If your calibration is correct your graph will start at 0N and then go to a positive value.

Calculate the mass and uncertainty of the iOLab for your report using Equation 3. Since you need to multiply/divide to calculate the mass you must also calculate (propagate) the uncertainty in a similar manner. Please refer to [error propagation](#) rules to determine the correct uncertainty.

The mass of the iOLab should be 200 g. What is the percent difference of the data? What is your percent uncertainty?

Include a properly labeled picture of the force-time graph that shows the change in force from sitting still to lifted up.

Ask for help if you need to understand how this applies to your calculation.

## Finishing Up

Now that you have completed the lab, be sure you filled out all portions of the data tables (templates found in the Resources Tool on [Sakai](#)), include figures, and develop a robust discussion using prompts found throughout the manual.

Ensure to give yourself enough time to complete the report and to hand it in by the due date as late lab reports will not be accepted! If you have any questions please attend a live lab

session to get help from one of the course lab demonstrators, or email [Phys1P91@brocku.ca](mailto:Phys1P91@brocku.ca).