

# PHYS 1P92 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 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 a wide variety of topics in PHYS 1P92. Some of these topics include fluids, thermodynamics, sound, and electricity and magnetism.

Hopefully you will also improve your digital skills as you collect, analyze, store, and present a lot of digital data. In this lab you will be introduced to a few sensors and techniques, 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 requires you to log in to 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 troubleshoot any issues you may be having.

Please be aware of any sensitive data like websites or usernames that may be visible. You **will** be disconnected if offensive material is shared with the class.

### 3.1 Magnetic fields

The iOLab has a built-in [magnetometer](#), which can detect magnetic field lines in 3 dimensions, and is one of the most sensitive instruments on the iOLab.

Magnetic field lines are a way of mapping magnetic forces through 3D space. In this lab, we will align the iOLab's  $y$ -axis with the Earth's magnetic north. In Figure 1 you see that the Earth's magnetic field points horizontal to the Earth's surface when you are at the equator, but at northern latitudes, such as Canada, it begins to dip down into the Earth.

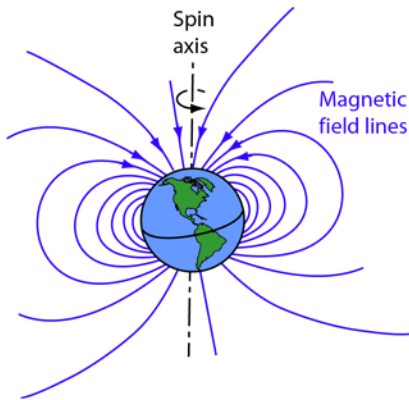


Figure 1: Schematic of the Earth's magnetic field.

Of course the magnetic field does not point exactly to the geographic north, where the axis of rotation is the Earth's true "North Pole". Using a compass on the surface of the Earth there is a slight **declination**, or angle between magnetic north and true north.

In a later lab, you will build a magnetic sensor from a simple circular loop of wire. It will sense magnetic fields **only when the magnetic field lines are passing through the loop** as seen in [this figure](#) in the OpenStax book. So imagine the iOLab magnetic field sensor having tiny loops of wire in each of the three axis, like in Figure 2.

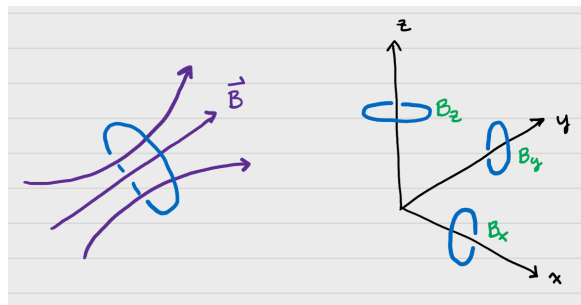


Figure 2: Only when magnetic field lines pass through the loop of wire is the field measured in that direction.

If you were to lay the iOLab flat on a table, parallel to the Earth's surface, and oriented it such that the y-axis was pointed towards magnetic north, which component of the Earth's magnetic field, if any, would each of the three axes be measuring? Which direction is each axis pointing, relative to the Earth?

### 3.1.1 Preparing the iOLab

We need to calibrate the iOLab magnetometer. Set your web browser to [iOLab Online](#), and plug the USB dongle into your computer. Click the green plus-sign under Get Data but **do not connect your iOLab**.

Next, click the green plus-sign under Settings. In order to use the 6-point calibration of the accelerometer, magnetometer and gyroscope, we first need to know the strength of the magnetic field in your location.

Find and record your current [latitude](#) (the east/west circles on a globe that tell you how far north/south you are) and [longitude](#) (the north/south circles on a globe that tell you how far east/west you are). If you prefer not to use your home address, you can use a nearby park, store, or pub as your location.

You can use either of these resources:

- [Google maps](#). After finding your location, right click on the spot. The two numbers on the pop-up window are your degrees north (of the equator) and west (of the Prime Meridian, running through Greenwich, England.) Do not record the negative sign, which for Google indicates west.
- [The Atlas of Canada - Toporama](#). Your coordinates are shown at the bottom of the map. Record them in decimal format.

Of course, these directions assume you are in Canada. If you are elsewhere in the world at the moment, adjust your numbers as being north/south and east/west accordingly!

Find and record the total strength of the Earth's magnetic field at your location

You can use either of these resources:

- [Natural Resources Canada Magnetic Field Calculator](#). Enter your latitude and longitude and click Calculate. Record the value of  $F$ , the total field strength, noting the units!
- [The US NOAA Magnetic Field Calculator](#). Enter your latitude and longitude, leave the Elevation to be "Mean sea level", and click Calculate. Record the

value of “Total Field”, noting the units!

Typically a "nano" unit is denoted with a n, and is  $1 \times 10^{-9}$  the standard unit. Example:  $1 \text{ nm} = 1 \times 10^{-9} \text{ m}$ . The same holds true for Teslas! Likewise a "micro" unit is denoted with the greek symbol mu ( $\mu$ ) and is  $1 \times 10^{-6}$  the standard unit. Example:  $1 \mu\text{m} = 1 \times 10^{-6} \text{ m}$ .

Once you have the strength of the Earth’s magnetic field in your location, enter it into the iOLab Online software, where it says “local  $B_{\text{Earth}} =$ ” (see Figure 3). **Enter the value with units of microtesla ( $\mu\text{T}$ ).**

Find a place as free from electronic and magnetic interference as possible before calibrating.

- Remove the magnets of the extra lab kit, your cell phone, and other electronic gadgets far across the room.
- Move away from any wires like keyboards, computer mice, headphones, wireless routers, etc.
- Do not move much more than 5 meters from the USB dongle, or communication might be interrupted.

*Yes, the magnetometer is that sensitive!*

**Connect your iOLab click the 6-point calibration button** (Figure 3) and proceed to follow the on-screen instructions for the 6-point calibration.

**Make sure your iOLab is facing the EXACT same way as the picture - use the axes to help check your orientation.** All 15 text boxes of calibration data should now have numbers populated in them.

### 3.1.2 Take data!

At the same location where you calibrated the iOLab, tape down a piece of paper, and place the iOLab with the positive z-axis pointed up (positive z points outwards from the face with the wheels). In iOLab Online, choose the Magnetometer sensor. Set the amount of data to collected as “-1” s, which indicates it will collect data from time you click Start to the

time you click Stop. Make sure you are looking at the magnetic field in the  $x$  direction by choosing  $B_x, \mu\text{T}$  from the data box drop-down menu. **All of these selections are highlighted in Figure 3.**

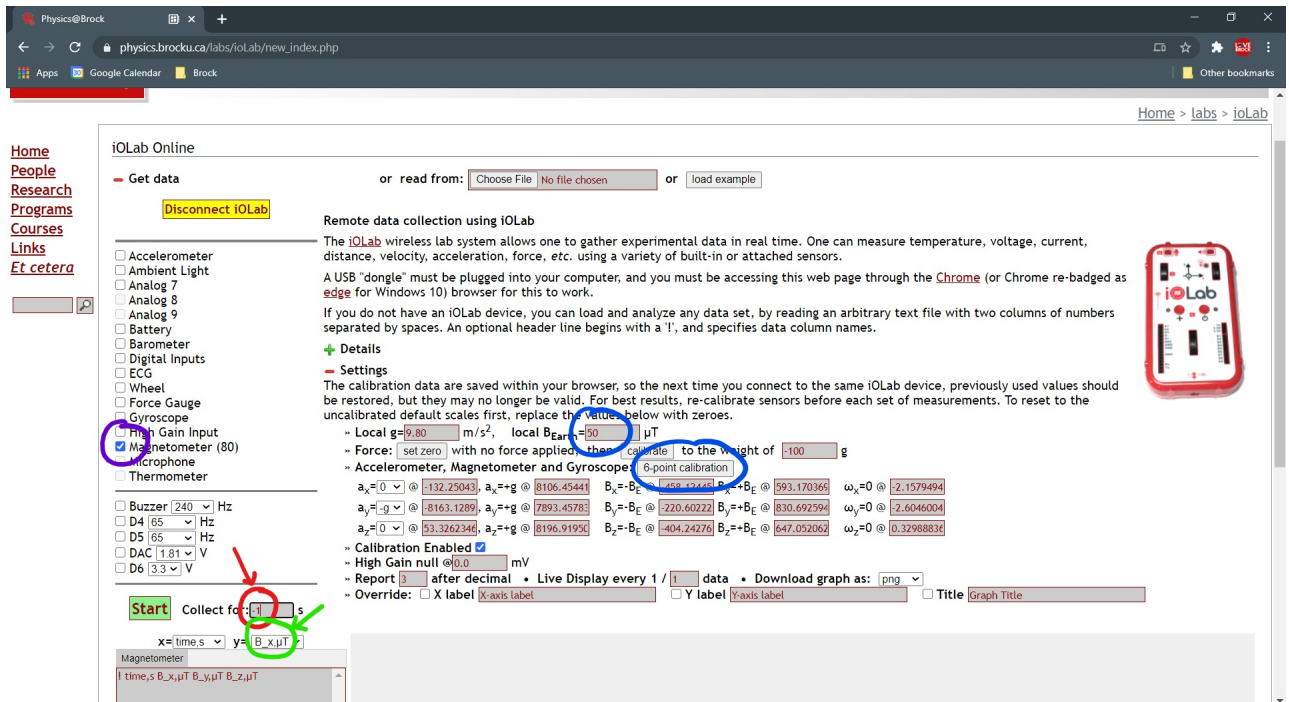


Figure 3: Location of selections in iOLab online.

Start collecting data, and slowly rotate the iOLab around the  $z$ -axis until the values of the  $B_x$  decreases to about zero. The data will jump around a lot, but should, by eye, appear to fluctuate around zero. **Stop the data collection, and don't move the iOLab!**

- Save the data to your computer.
- Save a graph of your adjustments of  $B_x$  for your report.
- With a pencil, carefully trace the long edge of the iOLab onto the paper, indicating north.
- Record the average and standard deviation of each of the three components of the magnetic field,  $B_x$ ,  $B_y$ , and  $B_z$  over the last second of your data, when the iOLab was well aligned.

Which component was strongest? The north/south direction or the vertical direction to the ground?

Verify the total magnetic field is close to that of your location, by calculating the Earth's magnetic field from the components, and including the uncertainty.

$$B_E = \sqrt{B_x^2 + B_y^2 + B_z^2} \quad (1)$$

**On a separate piece of paper write out your derivation of the uncertainty propagation equation, scan and submit it as a second file with your lab on Sakai. There are lots of free document scanner apps which can be used to scan and create files with your phone. Follow the instructions found [here](#).**

Download a compass app to your cell phone. There are many free apps for all cell phone types. If it needs calibrating, follow its instructions.

Move your iOLab, and lay your cell phone's long edge against the line you drew. How many degrees difference in compass heading do the two methods disagree? (You should be within 5° difference.)

At this point, you should ask yourself whether the iOLab y-axis was actually pointing north or south. How else could you tell?

Another method to measure the difference in compass heading is to point your cell phone so that it indicates north, and draw a line along the long edge of your cell phone on the paper, *that crosses the line of the iOLab*. You can use the protractor of the optical dish in your 1P92 kit to measure the angle between the lines.

## 3.2 LED light

The iOLab has a several connections on the front useful for learning about electronic circuits. Let's light up the laser light emitting diode (LED) that we will later use in optical experiments. Note that the laser LED is the LED with two wires coming out of it. The LEDs with rigid input connections will be used in future labs.

An [electrical circuit](#) is an interconnection of electrical components, such as the wires,

resistors, capacitors, and LED included in your kit. Current flows from the positive terminal of a voltage source, such as the batteries of the iOLab, through the components, and back into the negative terminus of the voltage source.

A diode is an electrical component that permits electrical current to flow through it *in only one direction*. An LED is a type of diode that also emits light. That uni-directional quality is important in the creation of all computing devices.

### 3.2.1 Preparing the iOLab

Set your web browser to the [iOLab Online](#) software, and plug the USB dongle into your computer. Turn on and connect your iOLab.

Take one wire, and plug the pointed end into the GND terminal on the iOLab. GND stands for “ground”, which is connected to the negative terminal of the iOLab batteries.

With a second wire, plug the pointed end into the 3.3V terminal of the iOLab. This connection is always on as long as the iOLab is on.

With the “alligator” clip ends of the two wires, attach them to the two leads of the LED.

**PLEASE DO NOT POINT THE LIGHT INTO YOUR EYES. THANK YOU.**

If you did this correctly, you have just made the simple circuit as shown in figure 4!

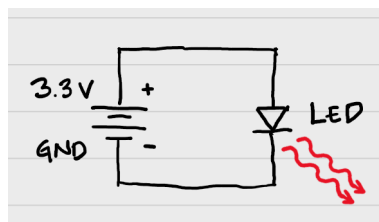


Figure 4: A simple diode circuit.

Did the LED light up? If not, what did you do to fix it? If it did, what could have gone wrong?

Take a photo of the lit up LED and add it to your lab report.



### 3.2.2 Take data!

Remove the wire lead from the 3.3V terminal and plug it into the terminal labelled DAC. This terminal has several voltage settings other than 3.3 V.

To turn on DAC, simply click the checkbox next to the label on iOLab Online. You don't need to be taking data to do so. For now, set it at 3.3 V, and connect your LED.

The LED will be a little dimmer. The DAC connection does not supply as much current as the 3.3V connection.

Select the Ambient Light sensor, and set it to take about 8 seconds of data. Place a shoebox, sweatshirt, or blanket over most of the iOLab to darken the light sensor, except for the LED light. You can hold up the cover a little to see what you are doing.

Carefully take the LED and direct the light into the light sensor, indicated by the light bulb icon on the front of the iOLab. While taking data, move the LED about, watching how the measured intensity of light rises and falls as the LED passes over the sensor.

Hold the LED steady (touching the iOLab) with its light directed into the light sensor. Take several seconds of data, and record the average and standard deviation of the last couple of seconds of light intensity.

Repeat this measurement for any 6 values of the DAC voltage from 3.3 V to 1.0 V.

Reload the iOLab Online webpage to clear the data box. Type in the data you just recorded, placing the DAC voltage on the x-axis, and the average light intensity on the y-axis. Use the largest standard deviation of light intensity at the uncertainty  $\Delta y$ .

Save this properly labeled graph for your lab report.

What is the trend of light intensity and applied voltage? Is there a minimum voltage to get the LED to turn on? (This is called the forward bias voltage.)

## 3.3 Dial tones and the microphone

Have you ever noticed the musical-like tones when you dial a number on the keypad of a phone? [Dual-tone multi-frequency signaling](#) is a hold-over from pre-digital days. Because telephone wires could carry signals with [frequencies](#) in the range of human hearing, early telephony equipment would listen for specific frequencies that indicated a press of a number

on a phone keypad.

Those frequencies are given in the [table here](#). You can play them from your cell phone or computer at [this website](#), or download a DTMF tone generator app for your cell phone.

Each number plays a combination of waves of two frequencies; for example, dialing the number “1” plays the following mathematical equation

$$\text{Tone} = \cos(2\pi f_1 t) + \cos(2\pi f_2 t) \quad (2)$$

where  $f_1 = 697$  Hz, and  $f_2 = 1209$  Hz.

In this part, we will use the iOLab microphone to listen to a keypad dial tone, and a feature of the iOLab Online to analyze the frequencies.

Adding two or more waves, such as simple cosine functions, with different frequencies can produce unusual interference effects. What does equation 2 look like, and how can find the two frequencies?

Go to the [Desmos graphing](#) calculator.

Enter the equation 2 above (using  $x$  for time). You can enter “ $\pi$ ” just by typing pi.

Add a second equation, this time only the first wave of frequency 697 Hz, and offset the graph by adding 2. Add a third equation of only the second wave of frequency 1209 Hz, but offset the graph by adding 4.

Using the “wrench” icon in the upper right, set the range of the  $x$ -axis to be (0.0, 0.02), and the  $y$ -axis range to be (-3.0,+6.0). Label the  $x$ -axis as “time (s)” and the  $y$ -axis as “amplitude”.

You should now see three curves; two cosine functions of different frequencies, and a wiggly third that is the sum of the first two.

Save a PNG picture of for your lab report. Go to the Share Graph icon in the upper right near the question mark icon, then select Export Image. Save whichever style you prefer.

### 3.3.1 Prepare the iOLab

In this part, you are recording sounds, so do this part in a quiet environment, without music or TV in the background. Set your web browser to the iOLab Online software, and plug

the USB dongle into your computer. Turn on and connect your iOLab.

**Change the number of significant digits of the data.** Under the Settings menu, change the value of “Report N after decimal” to 5. Select the Microphone sensor, and prepare to take about 2 seconds of data.

The microphone sensor records data at 4800 Hz, or 4,800 data points per second. In two seconds, that is 9,600 data points which may slow your computer a little when graphing that much data.

Unlike other high frequency sensors you may have used in other experiments, **we need all that data.** The highest frequency of a keypad dial tone is 1,477 Hz; the amplitude of that wave is going up and down so fast, in order to measure it, we need to measure *faster!*

Why did we change the number of significant digits displayed in the data?

### 3.3.2 Take data!

Using your computer speaker or cell phone, play the DTMF tone of any keypad number, and record that sound using the Microphone sensor. Save the data to your computer.

Change the graph into a “line” style graph, and zoom into any 0.02 seconds worth of data. Does it look like the Desmos graph you made above? Save this zoomed-in view of the experimental data for your report, to put alongside the theoretical data from Desmos.

**WARNING:** the iOLab microphone takes about 0.7 seconds to “warm up”. The initial data can be disregarded or deleted. If you choose to delete **do not delete the top line with !time,s MIC,arb**

A [Fourier transform](#) is mathematical transform of signal data (like our sound recording) that decomposes the signal into its frequencies. Fundamentally, it will tell us what frequencies are found in oscillating data as if it were a sum of cosines (just like equation 2).

**Don’t worry,** you will not need to know about the math of Fourier transforms. It has, however, been included for you as a new feature in iOLab Online, so that you can find the

frequencies that make up your data!

Zoom out to see the whole data set.

In the top right corner of the graph window, among the graph toolbox widgets, is a bar chart icon with a tool-tip "Toggle FFT" near the camera icon. Click it to add a second graph below the data. Then, use the box select to highlight and select about 0.3 seconds of data on the top graph.

A blue curve will appear in the second graph, with a few peaks. Switch to the “zoom” tool and zoom into the two largest peaks that appear first.

Save a graph of your data for your lab report showing;

- The selected data points that are being Fourier transformed
- A zoomed in view of the two largest frequency peaks in the bottom (frequency domain) graph.

Record the first two frequencies of the tone. This will be the  $x$ -axis values at their peak value. Were these what you expected?

How many peaks of frequency do you see overall? Why do you think this is?

## 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 [Phys1P92@brocku.ca](mailto:Phys1P92@brocku.ca).