

PHY 241

Lab 1- Introducing Uncertainty, Python, and the Pendulum

Learning Goals:

After completing lab 1, you should be able to

- 1) Recognize a **pendulum** and measure its **period** with a stopwatch.
- 2) Create a basic **scatterplot** of data in Python.
- 3) Use OneNote as a **lab notebook** that includes with plots, comments, and role specific contributions from each member of the group.
- 4) Calculate the **uncertainty** of a repeated measurement.

By the end of **lab 4**, you will need to be able to

- 5) Analyze a data set of hundreds of points collected by the instructor and determine which of 10 possible pendula that data set came from.

Introduction:

A **pendulum** is a mass swinging back and forth at the end of a string. A pendulum is one of the simplest interesting physical systems, because they have one value, the Period, which is easy to measure. **The Period, represented by the symbol T , is defined as the amount of time it takes an object to repeat its motion.** There are many questions we might ask:

- 1) Does the amount of mass make a difference?
- 2) Does the string make a difference?
- 3) Does the size of the swing make a difference?
- 4) Does the planet that the pendulum is on make a difference?
- 5) Does the support that is holding the pendulum at the top make a difference?

The answers to most of the questions above are surprisingly simple, however before we can answer any of them, we must be very specific with the phrase “make a difference.” Almost certainly if you measure the period of a pendulum two times in a row, you will get slightly different measurements. If it is exactly the same pendulum then those differences must be part of the **uncertainty of the measurement, δT** which we will calculate using “Standard Deviation.”

Equipment:

Mass

String

Metal stand

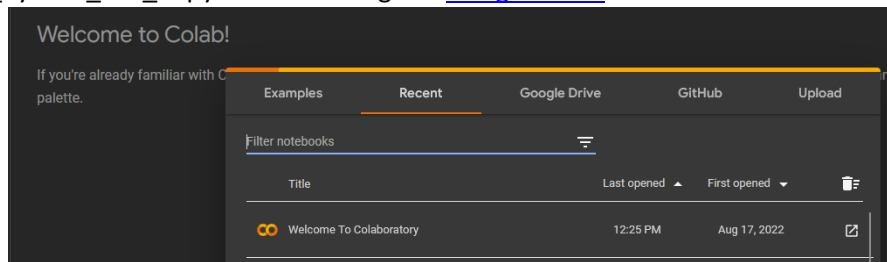
Stopwatch on your cell phone or computer

protractor

Computer with access to Microsoft OneNote (Please download Microsoft Office 365 directly from [UK](#)) and [Google Colab](#)

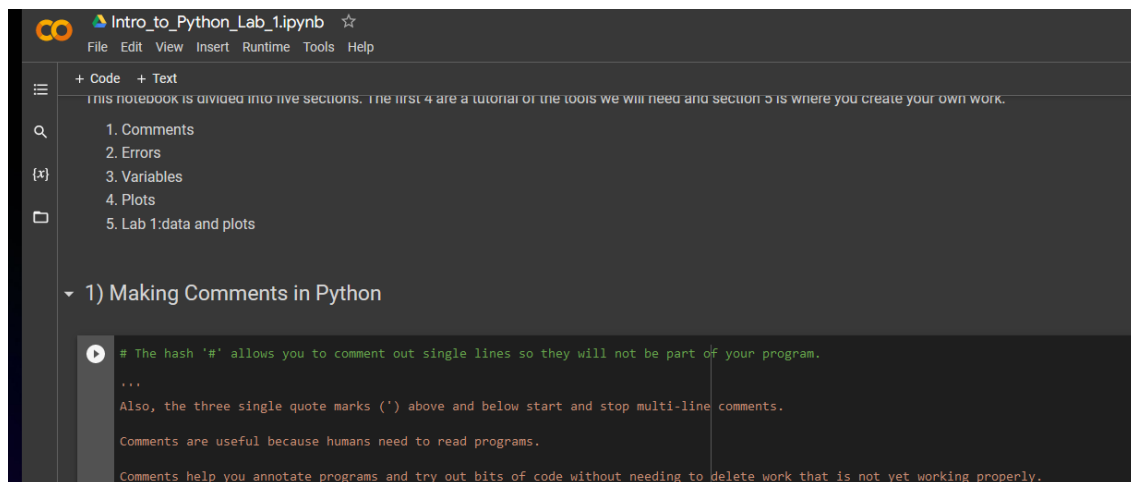
Task 1: Get Google Colab working.

- 1) **Picking roles:** For this first lab it is important that the person with the LEAST coding experience take the role of “Coder.” The other two roles: “Notetaker” and “Researcher” can be assigned randomly. Remember to rotate roles each week.
- 2) The Coder should go to Canvas-> Modules-> Lab 1 and download “Intro_to_Python_Lab_1.ipynb” and then go to [Google Colab](#). You should see a screen like



If not please login with your google account and then the above screen should appear.

We want to start by “Uploading” the “Intro_to_Python_Lab_1.ipynb” file we just downloaded from canvas. You should now see a screen like:



- 3) At this point you can “share” the colab file using the button in the top right corner. HOWEVER it is important that ONLY the coder change the file and run lines of code. Your code will crash if multiple people start running the same file in google colab at the same time.
- 4) As a group, work through the “Intro_to_Python_Lab_1.ipynb” file until you reach

▼ Lab 1 data and plots

The space below is reserved for you to collect data from the pendulum and plot it. Feel free to copy lines from above and edit them. If you need additional blocks of code, when you hover the mouse between blocks two buttons appear "+Code" and "+Text" that will give you additional space.

Task 2: Collecting data

- 5) For this first day of lab we will be repeatedly measuring the same "control" system and we will not have any "independent variables." Therefore, the Researcher should set up your pendulum so that it is swinging from the metal stand. Once you have set the length of string and amount of mass, **do not change these throughout the rest of this lab period.**
- 6) **Notetaker: Please "share" your OneNote Lab notebook with the rest of the group.** Everyone should be able to edit this in real time, however we still want the Notetaker to be the primary editor of this document.
- 7) **Notetaker: Record your string length and mass in the lab notebook. Your goal is to be able to "rebuild" the same pendulum next week.** Here are three examples of such a notation that have already been graded.

Bad Example **Who is in this group? What are the roles? -1 Group**

Tuesday, May 2, 2023 2:46 PM **No context given for measurements -2 N**

$m = 50$ $L = 70$ **All units are missing! -1 N**

$T = 1.2, 1.37, 4.2, 3.51, 1.2, 1.2, 1.2, 5$ **What is this symbol? -0.5 N**

A)

Lab 1 Maxwell
Thursday, May 4, 2023 9:39 AM

length of pendulum = 0.88m
mass = 11g

Period for 10 trials

Trial #	Period (s)
1	1.894
2	1.896
3	1.874
4	1.884
5	1.881
6	1.856
7	1.898
8	1.874

This mass is crazy small, just the hook is 50 g. -0.5 R

Does this length include the hook?

Great job with units

These numbers are way too similar for a stopwatch measuring a single swing at a time. -0.5 Group

B)

Lab 1: Pendulum
Tuesday, May 2, 2023 1:56 PM

Group members: Max B-Notetaker
Laura K-Coder
Margo A-Researcher

"Control" Pendulum

$L_{string} = 45cm$
 $m = 250$
 $\theta = 5^\circ$

Does m include the hook?

Great sketch for understanding measurements!

Incorrect definition of period -1 R

Period: time to swing from Left to Right.

Some missing units -0.5 N

This table should indicate measurements are in s.

Bad data: 0.51, 5.37,
Max: 1.12, 1.47, 1.12,
Laura: 1.34, 1.38, 1.29
Margo: 1.02, 1.22, 1.44

Moved to Python

```
[26] import numpy as np # Sometimes Google Colab will "disconnect"
import matplotlib.pyplot as plt

BadData=np.array([0.51, 5.37, 0.02])
MaxData=np.array([1.12, 1.47, 1.12])
LauraData=np.array([1.34, 1.38, 1.29, 1.38])
MargoData=np.array([1.02, 1.27, 1.44])
GoodData=np.concatenate([MaxData, LauraData, MargoData])
```

Coder- Nice work. You can still indicate these numbers are in s in the notebook.

- 8) **Researcher:** Get the pendulum swinging gently, at most the string should be 10° or less from vertical.
Using stopwatches, smart phones, and or the computer (search the web for "stopwatch") have all three members of the group measure the period of one swing of the pendulum.

We want a total of 10 different measurements of the period.

Important: if you have any obviously “bad data,” that should also be recorded and notated as “bad data.”

Remember: Falsifying data is a major breach of the student code of conduct and carries a minimum punishment of a zero on the assignment in question.

Task 3: Return to Colab and Perform Analysis

- 9) **Coder:** Return to Google Colab and enter the data you have collected into a variable that is assigned as an `np.array()`.

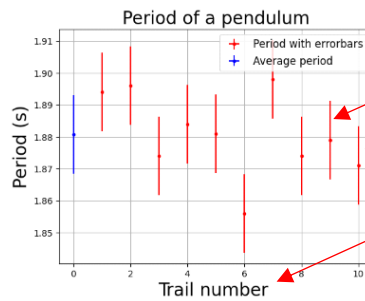
- 10) **Coder: Generate plots of your data and place them in your lab notebook.** Specifically:
 - a. We want a plot that compares “good data” with “bad data.”
 - b. We want a plot that compares all the “good data” with the average, (the average becomes a yvalue), and the standard deviation (the standard deviation becomes a y-error bar for the average).
 - c. *Here are some examples of what we are looking for with grading comments:*

Scatter plot of Period

Where is the comparison of good data and bad data? -2 Group

Double check your PDF export from OneNote to make sure the formatting is reasonable. (No Penalty since this is legible)

New Section 1 Page 1

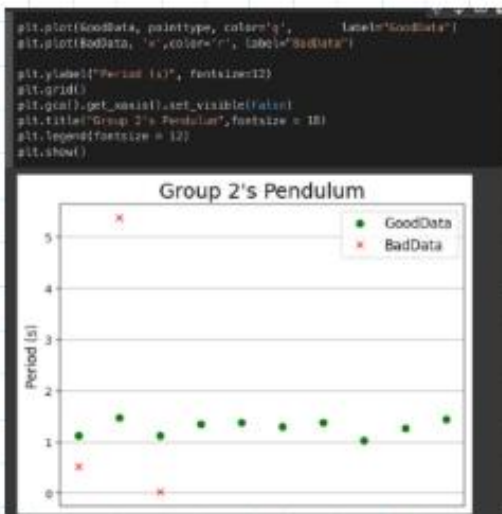


Individual data points should NOT have error bars unless they represent a collection of measurements. -0.5 C

Trial number is an ok x-axis, but it is better to emphasize that nothing changed between these trials.

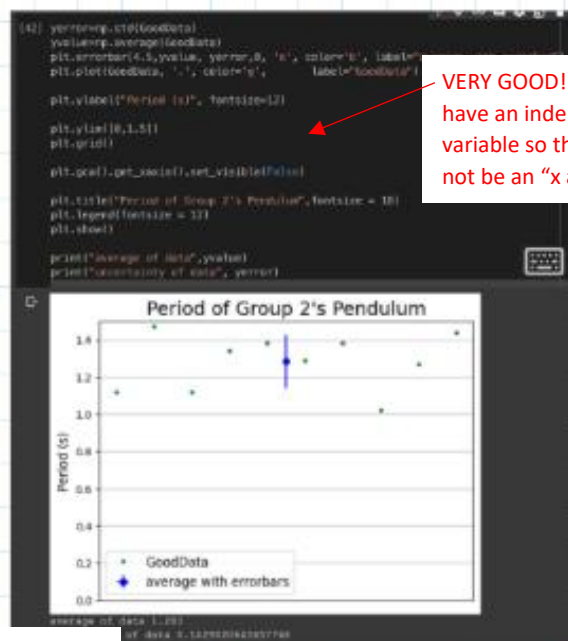
Our group determined that the period of our pendulum is 1.88 ± 0.025

Missing Caption! You should have something like: "This graph shows how our good data is summarized by a single blue data point with uncertainty." -1 R



We can clearly see that the bad data is ~~very~~ far from the good data and that we should not include data points when Max forgot to stop the timer.

I like the simple explanation of why the data is bad... but it does not explain why two of the data points are small instead of large. -0.5 R



VERY GOOD! We don't have an independent variable so there should not be an "x axis"

This should read: "Much farther than the uncertainty from the good data."

Missing Caption! You should have something like: "This graph shows how our good data is summarized by a single blue data point with uncertainty." -1 R

Our group determined that the period of our pendulum is 1.2835 ± 0.195

Rounding is determined by the first non-zero digit of the uncertainty! This should be 1.3 ± 0.2 s -0.5 R

- 11) **Researcher**: Create a caption for each of your graphs that explains the primary results that can be seen in the graph.
- 12) **Researcher**: Find numerical values for the average period, \bar{T} and its uncertainty, δT so you can confidently declare: "Our group determined that the period of our pendulum is $T \pm \delta T$ "

13) Once you are finished there are three different ways to get your file to pdf depending on the exact version of OneNote you are using:

A) Go to **File->Export->Page Select Format: PDF** to save the your notebook page onto one group members computer,

B) Or you can try **Share-> "Send Copy of Page"-> Email** to email to yourself a pdf of the file.

C) A final option if the two above do not work is **File-> Print, Destination->"Save to PDF"**

Once you have a pdf of your Notebook page, upload that pdf into canvas here. Only one group member needs to upload the file.