The Simple Pendulum

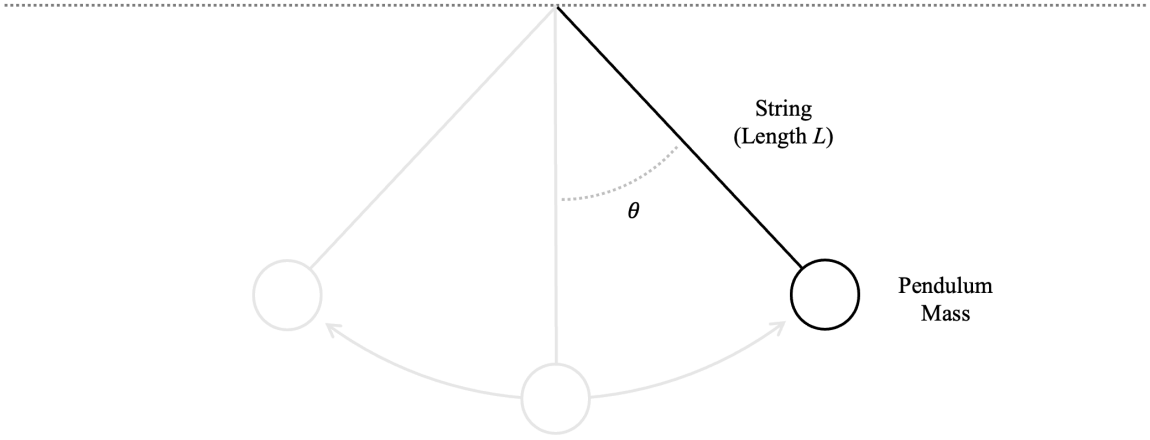
In-Person | One Week | Summary Submission

Introduction

The simple pendulum is a system which is composed of a pendulum "bob" – usually a ball – connected to a very light string (such that $m_{string} << m_{bob}$) and suspended from a height. The simple pendulum is then released, where simple harmonic motion is exhibited as the pendulum swings. This lab is designed to provide students with the opportunity to explore the various factors that could impact the period of a simple pendulum. This is a one-week lab with a summary due one week after completion of the lab. Students will (a) explore techniques for collecting data for a simple pendulum, (b) determine if starting angle and length influence the period of a simple pendulum, (c) experimentally determine the acceleration due to gravity using a simple pendulum, and (d) practice identifying and quantifying sources of error.

Theory

A simple pendulum is made up of a bob attached to a string and suspended from a height. For a pendulum to be considered simple, the mass of the bob must be significantly greater than the mass of the string.



Simple pendula exhibit simple harmonic motion, whereby they oscillate around an *equilibrium point*. The equilibrium point is defined as the point where the system would naturally rest. The lab today is designed to allow students the opportunity to explore the period of this simple harmonic motion for the pendulum.

While going through the derivation is a worthwhile process that you are encouraged to do, the period of a simple pendulum can be given as:

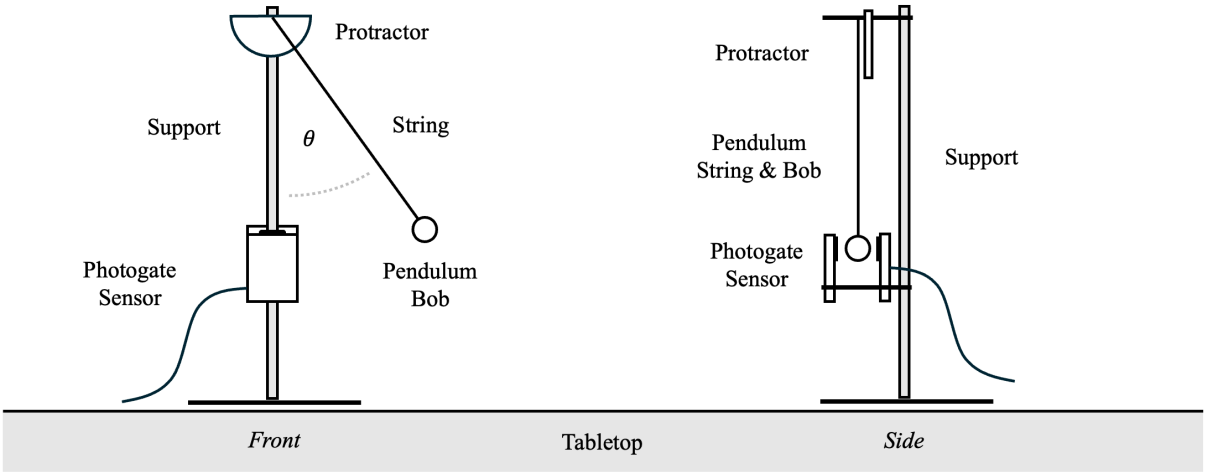
$$T = 2\pi\sqrt{\frac{l}{g}}$$

Where T is the period, l is the length of the pendulum, and g is the acceleration due to gravity. This equation utilizes a concept known as the *small angle approximation*, and part of the lab today will be about how applicable this concept is to real measurements.

Procedure

For this lab, we will utilize the following equipment:

- A pendulum bob and string
- A ring stand
- A meter stick
- A stopwatch (smartphone is fine)
- A photogate
- Data from second week of the Conservation of Energy lab
- A computer to analyze data with Vernier Graphical Analysis software package
- Excel (or equivalent) for analyzing data
- Word (or equivalent) for writing up the summary



Activity 1: Measuring the Period of a Simple Pendulum

1. Design your setup. Suspend a pendulum bob and string from the ring stand. Attach the photogate such that the bob travels straight through the photogate. It might be helpful to take a few practice runs to ensure a correct setup.

2. Measure the length of the pendulum. Record this value.

3. Beginning with a small angle (less than 10°), pull the pendulum bob back. Measure and record the starting angle.

4. Begin data collection using the photogate. Allow the bob to travel at least 5-10 *complete* cycles before stopping data collection.

5. Using the "Examine" tool in the Vernier Graphical Analysis software, find the average period of the pendulum. Record this value.

6. Repeat steps 3-5 for the same angle. How many total trials is up to you!

7. Average your trials together to find the average period of the pendulum. Record this value.

8. Using your length measurement and the equation provided for the period of a pendulum, find the expected period for your pendulum. Compare this value with what you found in step 7.

9. Repeat steps 3-8 but use a stopwatch to measure the period instead of the photogate.

10. Compare each method to each other and with what is expected. Be prepared to discuss each method (and the errors associated with each) in your discussion!

Activity 2: Changing Starting Angle

Note: *Activity 2 uses the data you should have saved from week two of the Conservation of Energy lab. Make sure you have that data saved, otherwise you will have to retake the data.*

1. Open your saved data from the conservation of energy lab.

2. For the first trial and angle, make a graph of the velocity vs time of the pendulum bob.

3. From this graph, and using multiple peaks (or troughs), find the average period of the pendulum for this angle. Record this value.

4. Repeat steps 2-3 for each trial of the first angle.

5. Find the average period for the first angle using all trial data. Record this value.

6. Repeat steps 2-5 for each angle.

7. Make a data table of the average period for each angle.

8. Make a graph of the average period vs angle.

Activity 3: Changing Pendulum Length

1. Using the photogate method from Activity 1, design an experiment to measure the period of a pendulum for various pendulum lengths. How many lengths? How many trials per length? It's up to you, but keep in mind the more data usually the better.

2. Make a graph using the average period and length values. Keep in mind we want to utilize this graph to find g, so you will want to think about what values to put on each axis.

3. Using your data/graph, find the acceleration due to gravity (g). Compare this with the expected value.

Analysis

In your submission, you will need to include:

- All graphs/data tables made in Excel.

- A summary data table for each activity (what were the key results/comparisons).

Discussion

As *parts* of your discussion, please make sure to include:

A description/discussion of each activity. What did you do/change/measure and what were the results? Consider thinking through things such as: What experimental method provided the most

“accurate” results? Is this expected? Are there any trends in your data? If so, what are they? If not, is this expected? How did you find g? Is your value accurate (is the true value within error bounds)?

For each activity, please discuss potential sources of error in the data collection. Consider systematic vs random errors and how each could apply to the data collection process. For your analysis, consider the assumptions that were made. For example, are there any non-conservative forces we’ve ignored? Be sure to discuss sources of error for each experimental method.

FAQ's & Recommendations

How should I prepare for lab time?

You only have so much time in lab each week, so proper preparation makes a huge difference in what you're able to accomplish! Read the handout ahead of time so that you can ask clarifying questions immediately and get started as soon as you arrive!

What goes in my lab notes?

The purpose of lab notes is to enable your or a colleague to reconstruct what was done and why after you've left the lab and are performing analysis or writing a submission.

- You can use any form you like to record experiment information: notebook, spreadsheet, etc.
- They don't have to be neat, in complete sentences, etc., but they do have to be useful!
- Make sure to take detailed notes about your setup, how to use the equipment, what results you found, measurements related to the environment you may need, etc. You may not be able to get back into the lab later in the week if you miss something, so record as much detail as possible!
- When storing multiple data files while in lab, make sure to name the files clearly so they're easy to find later.

When should I work on the experiment and analysis?

We strongly recommend doing the lab as early in the week as possible, rather than waiting until it is almost due. This is just so that, if you run into trouble and need help, you'll have plenty of time to talk to your TA and get issues resolved before the deadline.

How do I turn in my results?

After leaving lab, performing your analysis, and completing your submission, you're ready to turn in your work!

- Every lab session requires submission of either an assignment, summary, draft report, or report.
- Collaborate with your partners on data collection, analysis, and writing.
- Turn in a single group submission and make sure the names of all group members are included.
- Upload your submission to Canvas/Brightspace as a .pdf by the deadline in the course calendar.
- Other than the spreadsheet assignment, you will not upload any spreadsheets. Just copy and paste figures and other elements from your spreadsheet into your formal submission as needed.

Where can I get help?

Your lab TA can answer questions during the lab, by email, or by setting up a time to meet. You can also ask advice from lab partners and/or other students.

General DO's and DON'T's

- *DON'T* break the equipment – always be careful when using lab supplies!
- *DO* consult with your lab TA before leaving a lab session about your experimental method, the validity of your results, and any confusion you have about the analysis process.
- *DON'T* forget to record all the parameters and measurements for your experiment, including saving files.
- *DO* be creative in your experimental design and enjoy!