

The Simple Pendulum

Physics 114

Fall 2025

The goal of this lab is to investigate properties of the simple pendulum. You will determine whether the period of the pendulum depends on its length, mass, and amplitude.

Apparatus

A simple pendulum consists of a point-like bob of mass m suspended from a fixed point by a massless, inextensible string of length L . We don't have things like point-mass bobs and massless strings in real life, so you will use a small, spherical bob and a very light string. One end of the string is fixed to a support bar that is clamped to the lab table, and other end is tied to the bob. The bob is free to swing back and forth in an arc with a radius equal to the length of the string plus the radius of the bob.

The *period* of the pendulum's motion is the time it takes for the pendulum to complete one oscillation. The *amplitude* of the motion is the maximum displacement of the pendulum from its rest position. You can characterize the amplitude as the maximum angle $\theta_{\max}$ that the pendulum makes with the vertical as it swings; this is related to the maximum height $h_{\max}$ it reaches above its rest position by the equation

$$h_{\max} = L(1 - \cos \theta_{\max}). \quad (1)$$

If air resistance is negligible, conservation of mechanical energy tells us that the amplitude is equal to the initial angular displacement of the pendulum when released from rest.

To measure the period, you can use the stop watch on your phone or a photo gate that interfaces with the Vernier Graphical Analysis software on the lab computer. The photo gate records the time that the pendulum passes through it, which occurs twice per period. You can use a meter stick to measure the string length and maximum height, or a protractor to directly measure the maximum angle $\theta_{\max}$. Each method has advantages and disadvantages that you should consider before making your choice.

Part 1: Period and Mass

In this part, you are given two pendulum bobs with different masses and your goal is to determine whether the period of the pendulum depends on the mass of the bob. Measure the period for each pendulum

Question 1: What are the advantages and disadvantages of using the stop watch to measure the period, compared to the photo gate? Justify your choice for the method or combination of methods used to complete each of the three parts of this lab.

bob, taking care to keep the length L and amplitude $\theta_{\max}$ the same (measure these and record them in your lab notebook!). Take at least five trials for each bob so that you can estimate the uncertainty on the period from the standard error of the trials. Also, measure and record the mass of each bob.

Part 2: Period and Pendulum Length

Next, you will determine whether the period of the pendulum depends on its length. Choose five different string lengths and measure the period of the pendulum for each length, keeping the bob mass and amplitude the same (measure these and record them in your lab notebook!). It's best to use the heavier bob for this part. You only need to take one trial per string length in this part, and you can use your uncertainties from Part 1 to estimate the uncertainty on each period measurement. Make a plot of the period vs. length (period on the y axis, length on the x axis).

Part 3: Period and Amplitude

Your goal in this part is to determine if the period of the motion depends on the amplitude. Choose the heavier bob and a string length that makes it easier to get precise measurements of the period, then time the period for 6 different amplitudes between 0° and no more than 60° . If you choose to measure the period with the photo gate, you may find it difficult to aim the pendulum through the photo gate at the largest amplitudes; please be careful not to damage the photo gate. It's also important to maintain some tension in the pendulum string before releasing the bob, which is more difficult to do at larger amplitudes. Because of these experimental difficulties, you may want to take multiple trials at each amplitude if you have time. Estimate the uncertainty on each measurement of the period. Make a plot of the period vs. amplitude.

Formal Lab Report

You will write a formal lab report for this lab. Below I list all of the sections required in the report and the data, plots, and calculations that you need to include. Refer to the general lab report guidelines that are provided on Brightspace for more details on what to include in each section.

1. **Heading:** Your full name, your partners' full names, the date, and

Question 2: Does the period depend on the mass? Justify your answer with your data and your estimate of the period uncertainty.

Question 3: Does the period depend on the pendulum length? Justify your answer using your data, the plot of period vs. length, and the estimated uncertainty on the period measurements.

Question 4: Does the period depend on the amplitude? Justify your answer using your data, the plot of period vs. amplitude, and the estimated uncertainty on the period measurements.

Question 5: In a previous lab, you investigated a system consisting of a mass hanging vertically from a spring, and determined how its period depended on the mass and amplitude. Compare and contrast your results for the simple pendulum with your results for the mass hanging from a spring.

a title which includes the number and name of the experiment.

2. **Introduction:** Describe the goal(s) of the lab and introduce any theory or models that you will use or test to achieve those goals.
3. **Procedure:** Describe the apparatus and how you collected the data. You chose how to conduct the measurements this week, so you will need to describe your methods in enough detail such that a student who reads your report could reproduce your methods without ambiguity. Include a picture or detailed sketch of the apparatus. Answer Question 1 here.
4. **Raw Data:** Your measurements of bob masses, pendulum lengths, amplitudes, and periods in each part of the lab. Include the estimated uncertainties on the period measurements. It's a good idea to organize this data into tables, one for each part of the lab. Be sure to indicate units and use the correct number of significant figures, consistent with the measurement uncertainties.
5. **Data Analysis:** Include the plot of period vs. length in Part 2, and the plot of period vs. amplitude in Part 3. Each plot should have a title and axis labels with units. If you choose to use a linear trendline analysis as part of your results, include the trendline on the plot and report the values and uncertainties of any quantities relevant to your analysis, such as the slope or y-intercept of the trendline.
6. **Results and Discussion:**
 - (a) Part 1: state your measurement of the period for each bob with uncertainty in plus-minus notation, then answer Question 2.
 - (b) Part 2: answer Question 3.
 - (c) Part 3: answer Question 4.
 - (d) Answer Question 5.
 - (e) Suggest one source of random uncertainty and one source of systematic uncertainty that you think contribute a significant amount of uncertainty to your measurement. Describe how each one could affect your results and affect the conclusions you can draw from your result.
7. **Conclusions:** One paragraph that summarizes the important results and discoveries made in this lab.