

PHY 2020 — General Physics I Laboratory

The Simple Pendulum: Measuring g from a Graph

Name:	Date:
Lab partners:	

Purpose

To test the dependence of the period of a simple pendulum on its length and to use the experimental relationship between period and length to determine the local acceleration due to gravity, g.

Apparatus

Pendulum bob, string, support stand and clamp, meter stick, protractor (if available), and stopwatch. A cell phone stopwatch may be used. No balance is required.

Theory

For a simple pendulum undergoing small oscillations, the period T is related to the pendulum length L by

$$T = 2\pi \sqrt{L/g}$$

Squaring both sides gives a particularly useful form:

$$T^2 = (4\pi^2/g)L$$

Therefore, a graph of T^2 (vertical axis) versus L (horizontal axis) should be approximately a straight line. If the slope of this graph is m, then

$$m = 4\pi^2/g \quad \text{and therefore} \quad g = 4\pi^2/m.$$

Important: The pendulum length L is measured from the point of support to the center of the pendulum bob, not merely to the end of the string. Keep the initial angle small (about 10° or less).

Procedure

1. Construct a simple pendulum with a length of about 0.90 m. Measure L from the pivot point to the center of the bob and record it in the data table.
2. Displace the bob by a small angle (about 10° or less) and release it without pushing it.

3. Use the stopwatch to measure the time for 10 complete oscillations. One complete oscillation means that the bob returns to its starting position and is moving in the same direction.
4. Repeat the 10-oscillation timing once. Record both measurements and calculate their average.
5. Calculate the period T by dividing the average time for 10 oscillations by 10. Then calculate T^2 .
6. Shorten the pendulum and repeat the measurements for four additional lengths. Suggested lengths are approximately 0.75 m, 0.60 m, 0.45 m, and 0.30 m. The exact lengths are not important; measure the actual length each time.
7. On the graph paper supplied by your instructor (or on a separate sheet), plot T^2 on the vertical axis and L on the horizontal axis. Draw a single straight best-fit line through the data. Do not simply connect the dots. Position the line so that it follows the overall trend of the data, with the plotted points distributed reasonably evenly above and below the line.
8. Choose two well-separated points on your best-fit line (they do not have to be measured data points) and calculate the slope $m = \Delta(T^2)/\Delta L$.
9. Use the slope to calculate g from $g = 4\pi^2/m$.
10. Compare your experimental value with the acceleration due to gravity at Prince George's Community College in Largo, Maryland: $g = 9.80052 \text{ m/s}^2$. With ordinary student laboratory equipment and hand timing, disagreement of roughly 10–15% is not unusual.

Data

L (m)	Time for 10 oscillations #1 (s)	Time for 10 oscillations #2 (s)	Average time for 10 (s)	T (s)	T² (s²)

Graph and Calculation

Slope of best-fit line, $m =$ _____ s^2/m

Experimental value of $g = 4\pi^2/m =$ _____ m/s^2

Difference from $9.80052 \text{ m/s}^2 =$ _____ %

Questions

1. Does your graph support the prediction that T^2 is proportional to L ? Explain briefly.

2. If the pendulum length were increased by a factor of 4, by what factor should the period change?

3. Why is it better to time 10 oscillations than to time only one oscillation?

4. Would changing the mass of the pendulum bob be expected to change the period? Explain from the pendulum equation.

5. Suppose your value of g differs from 9.80052 m/s^2 by 10–15%. Does that by itself mean that the experiment failed? Give at least two experimental effects that could account for the difference.

6. Why should the release angle be kept fairly small in this experiment?

Instructor Notes (not part of the student handout)

Why this lab works well for a one-hour evening laboratory

The apparatus is minimal, no mass measurement is needed, and all data can be collected with a meter stick and a stopwatch. Students may use the stopwatch function on their cell phones. Five pendulum lengths with two 10-cycle timings each normally provide enough data for a useful hand-drawn graph without making the exercise tedious.

Graph-paper instruction is an intentional part of this experiment. Many students may have little or no experience constructing a graph by hand. Before they begin plotting, demonstrate how to choose convenient axis scales, label each axis with the quantity and units, use most of the available graph-paper area, plot points accurately, draw a straight best-fit line rather than connecting successive points, and determine the slope from two well-separated points on the best-fit line.

Suggested timing

Activity	Approx. time
Introduction / demonstration	5–8 min
Data collection	20–25 min
Calculations and hand graph	15–20 min
Questions / checkoff / cleanup	5–10 min

Practical notes

- Groups of 3–5 can work well: one student operates the stopwatch, one counts oscillations, one measures length, and the others record/check calculations. Students should rotate roles if desired.
- The most common mistake is measuring only the string length. The effective length is from the pivot to the bob's center of mass.
- Have students begin timing as the bob passes a clearly defined reference point rather than trying to start the watch exactly at release.
- Timing 10 periods reduces the fractional effect of human reaction time. If time permits, 20 periods gives still better timing, but 10 keeps the lab comfortably under an hour.

- A 10–15% discrepancy in g is entirely acceptable with ordinary student equipment if the procedure and calculations are sensible. Grade the physics and method rather than proximity to 9.80052 m/s^2 .
- If graph paper is inconvenient tonight, students can still estimate the slope using the first and last data points, but a hand-drawn best-fit graph is pedagogically preferable.
- Optional extension if a group finishes early: choose one fixed length and compare the measured period for release angles of roughly 5° , 15° , and 30° . Ask whether the small-angle formula appears adequate at the precision of the experiment.

Suggested grading (10 points)

Item	Points
Complete, plausible data	2
Calculations of T and T^2	2
Graph and slope	2
Calculation of g	2
Analysis questions / physical interpretation	2

The rubric intentionally does not assign points for formal significant-figure rules. Students should carry enough digits to avoid excessive rounding and report a sensible numerical result.