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# Free sample lesson

The Simple Pendulum, from the Oscillations Starter Pack

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**01** The Simple Pendulum

Simple pendulum • 45 min

Student worksheets

Experiment links

Prediction questions

Data tables

Answer explanations

Teacher guide

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# The Simple Pendulum

**Simulation:** Simple pendulum    **Time:** about 45 min    **Level:** Grades 9–12 • intro college

Name \_\_\_\_\_

Date \_\_\_\_\_

Class \_\_\_\_\_

**Open the experiment:** in PSL, search for “Simple pendulum”.  
Link: [pslsimulations.com/#/lab/mechanics-lab/pendulum](https://pslsimulations.com/#/lab/mechanics-lab/pendulum)

## Learning goals

- Measure how a pendulum's period depends on its length.
- Find the release angle where the small-angle formula  $T = 2\pi\sqrt{L/g}$  stops being accurate.

A pendulum's period  $T$  is the time for one complete back-and-forth swing. For small swings, physics predicts  $T = 2\pi\sqrt{L/g}$ , where  $L$  is the length and  $g = 9.81 \text{ m/s}^2$ . The simulation shows this “small-angle period” as a readout, but it actually models the full swing at any angle. Your job is to find out when the readout stops telling the truth.

**Controls you'll use:** Length (0.5–3 m) • Release angle (5–150°) • readout: Small-angle period

## 1 • Predict

Before you touch the simulation

**P1** If you make the pendulum 4 times longer, its period will...

☐ stay the same    ☐ double    ☐ become 4 times longer    ☐ halve

How sure are you? (1) (2) (3) (4) (5) (1 = guessing, 5 = certain)

**P2** Does the release angle change the period? Predict the period at 10° and at 120° for a 1.5 m pendulum.

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**P3** At roughly what angle do you think the formula will be off by more than 5%?

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## 2 • Investigate

Change one thing at a time

### Part A • Length

1. Set the release angle to 10°. Keep playback at 1×
2. For each length, read the Small-angle period, then time 5 full swings with a stopwatch and divide by 5.

| Length $L$ (m) | Readout $T$ (s) | Time for 5 swings (s) | Measured $T$ (s) | $T^2$ (s <sup>2</sup> ) |
|----------------|-----------------|-----------------------|------------------|-------------------------|
| 0.5            |                 |                       |                  |                         |
| 1.0            |                 |                       |                  |                         |
| 1.5            |                 |                       |                  |                         |
| 2.0            |                 |                       |                  |                         |
| 3.0            |                 |                       |                  |                         |

### Part B • Angle

1. Set the length to 1.5 m. The readout should say 2.46 s.

2. For each release angle, time 5 full swings and find the measured period. Then find the % difference:  $(\text{measured} - 2.46) \div 2.46 \times 100$ .

| Release angle | Time for 5 swings (s) | Measured T (s) | % difference from 2.46 s |
|---------------|-----------------------|----------------|--------------------------|
| 10°           |                       |                |                          |
| 35°           |                       |                |                          |
| 60°           |                       |                |                          |
| 90°           |                       |                |                          |
| 120°          |                       |                |                          |
| 150°          |                       |                |                          |

### 3 • Explain

Use your data

**E1** Use your Part A data: what happened to the period when the length went from 0.5 m to 2.0 m (4 times longer)? Was your prediction P1 right?

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**E2** Plot  $T^2$  against L. Describe the graph and find its slope. Use slope =  $4\pi^2/g$  to calculate g.

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**E3** From Part B, at which angle did the measured period first differ from the readout by more than 5%?

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**E4** The formula assumes  $\sin \theta \approx \theta$ . Explain why a pendulum released at a large angle takes longer to swing than the formula predicts.

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#### Exit ticket

A grandfather clock has a 1.0 m pendulum. (a) Calculate its period. (b) If the pendulum is pushed into wider swings, will the clock run fast or slow? Why?

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# The Simple Pendulum

**Simulation:** Simple pendulum    **Time:** about 45 min    **Math:** Algebra, square roots (graphing optional)

**Experiment link:** [pslsimulations.com/#/lab/mechanics-lab/pendulum](https://pslsimulations.com/#/lab/mechanics-lab/pendulum)

## Overview

Students confirm  $T \propto \sqrt{L}$ , then discover that the familiar formula is an approximation that fails for wide swings. The simulation integrates the full nonlinear equation  $\theta'' = -(g/L) \sin \theta$ , so timed periods at large angles really are longer than the readout. Swings run in real time at 1 $\times$ : we timed 2.47 s at 10° and 3.37 s at 120° for  $L = 1.5$  m.

## Before class

Open the simulation once before class. Students need a stopwatch (phones work). Pairs work well: one releases with Reset, one times.

## Common misconceptions

- Heavier bobs swing faster. (Mass does not appear in the formula; the simulation uses a point mass.)
- Doubling the length doubles the period. (It multiplies the period by  $\sqrt{2} \approx 1.41$ .)
- Amplitude never matters. (It does at large angles, which is the point of Part B.)

## Answer key with explanations

|               |                                                                                                                                                                                                                                                                                                          |
|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>P1</b>     | Double. $T \propto \sqrt{L}$ , so 4 $\times$ the length gives $\sqrt{4} = 2\times$ the period.                                                                                                                                                                                                           |
| <b>P2</b>     | At 10° the period is about 2.46 s, the same as the readout. At 120° it is about 3.37 s, roughly 37% longer.                                                                                                                                                                                              |
| <b>P3</b>     | Any reasonable guess. The real answer, found in Part B, is about 50°.                                                                                                                                                                                                                                    |
| <b>Part A</b> | Readouts: 0.5 m $\rightarrow$ 1.42 s, 1.0 m $\rightarrow$ 2.01 s, 1.5 m $\rightarrow$ 2.46 s, 2.0 m $\rightarrow$ 2.84 s, 3.0 m $\rightarrow$ 3.47 s. Timed values should agree within about 0.1 s. $T^2$ values: 2.01, 4.03, 6.04, 8.05, 12.1 s <sup>2</sup> .                                          |
| <b>Part B</b> | Expected measured periods at $L = 1.5$ m: 10° $\rightarrow$ 2.46 s (+0.2%), 35° $\rightarrow$ 2.52 s (+2.4%), 60° $\rightarrow$ 2.64 s (+7.3%), 90° $\rightarrow$ 2.90 s (+18%), 120° $\rightarrow$ 3.37 s (+37%), 150° $\rightarrow$ 4.33 s (+76%).                                                     |
| <b>E1</b>     | The period doubled (1.42 s $\rightarrow$ 2.84 s). Quadrupling the length doubles the period because $T \propto \sqrt{L}$ .                                                                                                                                                                               |
| <b>E2</b>     | A straight line through the origin, slope $\approx 4.0$ s <sup>2</sup> /m. $g = 4\pi^2 \div 4.02 \approx 9.8$ m/s <sup>2</sup> . Student values within about 5% are good.                                                                                                                                |
| <b>E3</b>     | Between 45° (4.0%) and 60° (7.3%). The 5% crossover is at about 50°.                                                                                                                                                                                                                                     |
| <b>E4</b>     | The restoring force is $mg \sin \theta$ . At large angles $\sin \theta$ is noticeably smaller than $\theta$ ( $\sin 90^\circ = 1$ , while $90^\circ = 1.57$ rad), so the pull back toward the center is weaker than the formula assumes. Weaker restoring force means slower return and a longer period. |
| <b>Exit</b>   | (a) $T = 2\pi\sqrt{(1.0/9.81)} \approx 2.01$ s. (b) Slow. Wider swings have a longer period, so the pendulum completes fewer swings per hour and the clock loses time.                                                                                                                                   |

### Extension

Ask students to predict, then measure, the period on the Moon ( $g = 1.62 \text{ m/s}^2$ ) using the formula only, and explain why the simulation cannot test this directly.

### Differentiation

Support: give the  $T^2$  column pre-filled and skip the slope. Challenge: compare Part B with the series  $T \approx T_0(1 + \theta_0^2/16)$ , with  $\theta_0$  in radians, and find where it breaks down.

## Like this lesson?

This sample is Lesson 1 of the **Oscillations Starter Pack**. Every PSL lesson pack gives you print-ready student worksheets, direct experiment links, prediction questions, data tables, answer explanations and a teacher guide.

### 3 LESSONS

#### **Oscillations Starter Pack: \$19**

The Simple Pendulum · Resonance in a Driven Spring · Coupled Pendulums and Energy Transfer

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Get them at [pslsimulations.com](https://pslsimulations.com) under **Lesson packs**.