Simple pendulum: $T^2 = f(L)$

FizziQ activity · High school · 35 min

Scan to open in FizziQ

The FizziQ Web pendulum simulation runs in a browser: students vary length and amplitude, plot T^2 against L and read g from the slope. Computer, high school.

Learning objectives

- Measure the period of a simple pendulum for different lengths
- Verify the isochronism of small oscillations (T independent of amplitude)
- Verify $T = 2\pi\sqrt{L/g}$ by plotting T^2 versus L
- Determine g from the slope of the $T^2(L)$ graph
- Identify the limit of the small-angle approximation

Instruments and sensors

FizziQ Web Pendulum simulation

Materials

- Computer, tablet, or smartphone with FizziQ Web
- Note: the protocol relies on the FizziQ Web Pendulum simulation and remains adaptable to any equivalent simulation or video-tracking setup for angle-versus-time measurements.

Protocol

1. Open the Pendulum simulation in FizziQ Web (Experiment → Simulations → Pendulum).
2. Part 1 — Effect of length: set the initial angle to 10° (small angle). Set the length to 0.25 m.
3. Select angle versus time recording. Start the simulation with REC. Record a few oscillations, then stop.
4. In the experiment notebook, measure the period T (time between two passages at the same angle in the same direction). Note the value.
5. Repeat for lengths 0.50 m, 0.75 m, 1.00 m, 1.50 m, and 2.00 m. Note T for each length.
6. Create a table: Length L (m), Period T (s), T^2 (s^2). Plot T^2 versus L. Is it a straight line through the origin?
7. The slope of $T^2(L)$ equals $4\pi^2/g$. Calculate g and compare with 9.81 m/s^2.
8. Part 2 — Effect of amplitude: set the length to 1.00 m. Measure the period for initial angles of 5°, 10°, 15°, 20°, 30°, 45°, and 60°.
9. Note T for each angle. For which angles is the period essentially identical? At what angle does the period start to increase noticeably?
10. Conclusion: $T = 2\pi\sqrt{L/g}$ is an excellent approximation for small angles (< 20°). For large angles, the period increases slightly and depends on amplitude.

Expected results

Part 1: T increases with length. For $\theta = 10°$: $T \approx 1.00$ s (L = 0.25 m), 1.42 s (0.50 m), 1.74 s (0.75 m), 2.01 s (1.00 m), 2.46 s (1.50 m), 2.84 s (2.00 m). The $T^2(L)$ graph is a straight line through the origin with slope $4\pi^2/g \approx 4.03$ s^2/m. Part 2: for angles up to 20°, T is essentially constant. At 45°, T increases by about 4%; at 60°, by about 7%.

Questions

- If you double the pendulum length, does the period double?

- Why does the pendulum mass not appear in the period formula?
- At what angle does the small-angle approximation start to fail?
- How could you use a pendulum to measure the value of g?
- Why is the graph $T^2(L)$ more useful than $T(L)$?
- What would the period be on the Moon ($g = 1.6$ m/s^2)?

Going further

- Use the simulated pendulum to 'measure' g on different planets by comparing periods
- Plot the centripetal acceleration versus time and identify when the velocity is maximum
- Investigate the effect of very large angles (90° or more) on the motion
- Compare the simulation with a real pendulum experiment using the smartphone accelerometer
- Determine the pendulum length needed for a period of exactly 1 second