

PHY 222 LAB 11-2: Pendulum

Objective: Use video analysis to study the motion of a pendulum using the Angular Momentum Principle.

Background

A simple pendulum is composed of a string and mass (0.2 kg) as shown in Figure ??.

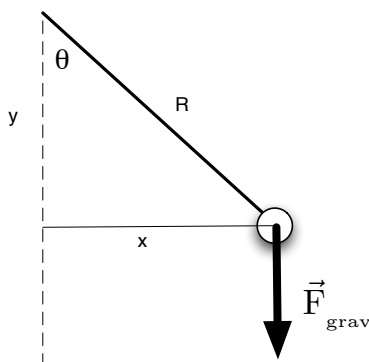


Figure 1: A simple pendulum.

The gravitational force on the mass exerts a torque on the pendulum that changes its angular momentum, according to the Angular Momentum Principle. Calculate torque and angular momentum about the pivot.

$$\begin{aligned}\vec{\tau}_{\text{net}} &= \frac{d\vec{L}}{dt} \\ \vec{\tau}_{\text{grav}} &= \frac{d}{dt}(\vec{r} \times \vec{p}) \\ \tau_z &= \frac{d}{dt}(Rp) \\ &= mR \frac{dv}{dt} \\ &= mR \frac{d}{dt}(R\omega) \\ &= mR^2 \frac{d\omega}{dt} \\ &= mR^2 \frac{d^2\theta}{dt^2}\end{aligned}$$

In this experiment, you are going to graph the torque due to the gravitational force ($\tau = Fx$) vs. the angular acceleration ($\alpha = \frac{d^2\theta}{dt^2}$), and from your graph you will measure the moment of inertia of the pendulum ($I = mR^2$). Using the moment of inertia, you will calculate mass of the pendulum and compare it to what you measure with a balance.

Experiment

1. Go to our course web site and download the video 11-2-pendulum-3cycles.mov.
2. Import the video into Logger Pro for analysis.

3. Set the origin to be at the pivot and use the meterstick to calibrate distance in the video.
4. Mark the position of the mass as it swings from the far right to the far left. You should mark the top edge of the green sticker. (In fact the top edge is probably still a bit lower than its center of mass. Be consistent.)
5. Create a new calculated column for $R = \sqrt{x^2 + y^2}$.
6. Create a new calculated column for θ . Use the function `atan2(x, -y)` (see the triangle in the picture above).
7. Create a new calculated column for $\omega = \frac{d\theta}{dt}$.
8. Create a new calculated column for $\alpha = \frac{d^2\theta}{dt^2}$.
9. Create a new calculated column for $\tau = Fx$.
10. Graph τ vs. $\frac{d^2\theta}{dt^2}$. Do a linear fit to the linear portion of the graph. Do not include data on the edges of the curve since the derivative function for the end data points has numerical error.

What is the equation for the linear curve fit?

What does the slope represent?

Use the slope to determine the mass of the pendulum.

Compare the mass of the pendulum determined from the curve fit to its actual mass, 0.2 kg. Calculate the percent difference in the values.

The torque on the pendulum can be written as $mgR\sin(\theta)$. Write a differential equation that relates θ , t , g , and R .

Fit a curve to θ vs. t and use your curve fit to determine the frequency f and period T for the pendulum.

The theoretical period of a pendulum with small angle oscillations is $T = 2\pi\sqrt{\frac{L}{g}}$ where L is the length of the pendulum. In this experiment, we called it R . Calculate the period of the pendulum from theory using the average radius R measured from the data in the video.

What is the percent difference between the measured period and the calculated (theoretical) period of the pendulum?