Name: ______________________________

LAB 14. PHYSICAL PENDULUM

Introduction

Sometimes it is useful to know the rotational inertia of an object; for instance, in automobile collision analysis. In this lab, we will experimentally determine a rotational inertia of an object from its behavior as a physical pendulum.

Theory

An extended object hanging from an axis of rotation that does not pass through its center of mass acts as a pendulum. When its center of mass is directly below the axis; its weight mg produces no torque; however, when its center of mass is displaced by an angle θ, its weight produces a restoring torque τ of $-Lmg \sin\theta$, where L is the distance from the axis to the center of mass. If θ is small, we can make the small-angle approximation that $\sin\theta \approx \theta$, measured in radians. Then the pendulum behaves as a torsional Hooke's law oscillator with angular frequency ω set by $\omega^2 = Lmg/I$, where I is its rotational inertia. Therefore, I can be calculated from ω, L, and m.

By the parallel axis theorem, the rotational inertia I of the pendulum about its axis is $I = I_{CM} + mL^2$. So, $I_{CM} = I - mL^2$.

Experiment

In this activity you will measure the mass, find the center of mass of, and time the oscillations of a physical pendulum. From that, you will determine ω, I, and I_{CM}.

Supplies

Hoop, clamp stand, clamp with knife edge, stopwatch.

Data Collection

Setup

1. (18 points) Measure the mass and dimensions of the hoop.

   Mass: ____________ Inner diameter: ____________ Outer diameter: ____________

2. Hang the hoop on the knife edge.

Measurements

1. Displace and release the hoop so that it swings back and forth.
2. (12 points) Time a whole number of complete cycles of the oscillation. Use at least ten oscillations; more if the oscillation is rapid. Start the timer on "zero" and stop at the desired number of oscillations.

   Number of oscillations: _______ Time: _________

Derivations

1. (8 points) Write the formula for ω^2 in terms of T.

2. (8 points) Solve $\omega^2 = Lmg/I$ for I.

3. (8 points) Substitute the expression you just derived for I into $I_{CM} = I - mL^2$ and simplify.

Data Processing

Show your work. Report the units.

1. (8 points) Divide the time by the number of oscillations to estimate the period T.

   T: ______________

2. (8 points) Calculate ω^2.

   ω^2: _____________

3. (8 points) Calculate I_{CM}.

   I_{CM}: ____________

Analysis and Discussion

1. (10 points) What is the theoretical moment of inertia I_{CM} of the object about its center of mass? Use the appropriate formula with the dimensions and mass of the pendulum.

2. (4 points) Does your empirical I_{CM} match the theoretical I_{CM}?

3. (8 points) Comment on your empirical and theoretical I_{CM}.

Lab Report

Turn this in.