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 $-dmg \sin\theta$, where d 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 $\omega^2 = dmg/I$, where I is its rotational inertia. Therefore, I can be calculated from ω, d, and m.

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

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. Measure the mass and inner diameter of the hoop.

   Mass: _____ Inner diameter: _____

2. Hang the hoop on the knife edge.

Measurements

1. Displace and release the hoop so that it swings back and forth.
2. 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. Find the formula for ω^2 in terms of T.

2. Solve $\omega^2 = dmg/I$ for I.

Data Processing

1. Divide the times by the number of oscillations to find an estimate of the period T.

   T: _____

2. Calculate ω^2.

   ω^2: _____

3. Calculate I.

   I: _____

4. Calculate I_{CM}.

   I_{CM}: _____

Lab Report

Turn this in.