5.6: Physical Pendulum

Name: ____

Date: ______________________

Partners:____

Equipment

- *LabPro* Interface
- *Rotation* software file
- Rotary encoder
- Rotational inertia accessories
- Meterstick

I. Basic Parameters

Open the file *Rotation.*

Orient the rotary encoder as shown above. Remove the 3-step pulley and flip it over so that the largest radius pulley is furthest from the encoder. Attach the long metal rod to the encoder and center the rod between the plastic pins for stability. Attach an adjustable mass to the rod 24 cm from the pivot point.

Since the initial orientation of the encoder is automatically set as 0°, press **Collect** and, *after the encoder begins to collect data*, rotate the meterstick to about 10° from its natural resting position and let it go.

Rescale your graph until two complete cycles of the motion are clearly visible. Display both angular position and angular velocity vs. time. Print your graph and attach it to the end of this activity.

Question: Describe your graph. What is the relationship between the angular position and angular velocity? How do the maxima, minima and zeroes of the two functions relate to each other?

Display both angular velocity and angular acceleration vs. time.

Question: Describe your graph. What is the relationship between the angular velocity and angular acceleration? How do the maxima, minima and zeroes of the two functions relate to each other?

The period of the motion is the time for one complete cycle of the motion. To very accurately determine the period, rescale your graph until ten complete cycles of the motion are clearly visible. Accurately measure the time needed for ten cycles and divide by ten to determine the period.

Question: What is the period of the motion?

II. Dependence of Period on Mass Position

The pendulum you have been examining is referred to as a *physical pendulum*, as opposed to a *simple pendulum*, which is simply a massive bob on the end of a thin string or rope. In this series of exercises, you will investigate the period of this pendulum as a function of the position of the adjustable mass relative to the pivot point.

Question: Your original period was for the mass located 24 cm from the pivot point. If the mass is slid upward until it is only 20 cm from the pivot point, do you think the period will change? If so, how? Explain.

Move the mass until it is 20 cm from the pivot point and accurately measure the period of the resulting motion. Record your result in the table below.

Question: Does the result agree with your prediction? If not, can you explain why the period changed in the manner that it did.

The dependence of period on clamp position is not a simple one. To analyze this dependence in more detail, take measurements to complete the following table. Always start the motion from the same initial angular orientation.

Mass Position (m)	Period (s)

0.24	±
0.20	±
0.16	±
0.12	±
0.08	±
0.04	±

Create a graph of period vs. mass position.

On your graph, include a line representing the theoretical value for the period of a *simple pendulum* with length given by the location of the adjustable mass. This would be the period if the adjustable mass where simply hung from a string and oscillated back and forth.

Question: Based on your graph, does your pendulum behave like a simple pendulum? If not, is there a region on the graph where the dependence is more similar to a simple pendulum? If so, explain why the pendulum is "simpler" for these values of position than for other values of position.

III. Theoretical Explanation

The period of the pendulum depends upon the position of the adjustable mass in a non-linear manner. Your task is to derive this dependence and see if your data matches this theoretical prediction.

To ease the analysis, we will make a pair of simplifying assumptions. First, although the rod is not pivoted about its actual endpoint we will approximate the system as if the pivot point is at the endpoint of the rod. Second, we will approximate the adjustable mass as a point mass.

Question: Draw a free-body diagram for the pendulum displaced by a small angle, θ, from equilibrium. With L as the length of the metal rod, m as the mass of the rod, d as the location of the adjustable mass measured from the pivot point, and M as the adjustable mass, apply the rotational form of Newton's second law, with the direction of displacement positive.

Question: Use the small-angle approximation:

and the definition of angular acceleration:

to simplify your equation.

Question: Collecting constants, you should now have a differential equation with a known solution. Based on this solution, write an expression for the period of the meterstick.

Question: Determine numerical values for all of your constants and simplify your theoretical expression below.

Add your theoretical model for period to your graph of period vs. mass position. Clearly distinguish between the physical pendulum model, the simple pendulum model, and the actual data. Print your graph and attach it to the end of this activity.

Question: Does you theoretical model accurately represent your experimental data? What could you have done to improve the agreement between theory and experiment?