5.13: Rotational Motion

Name: ____

Date: ______________________

Partners:____

Equipment

- *LabPro* Interface
- Rotary encoder
- *Rotation* software file
- Hanging masses

Introduction

The rotary encoder is a rotational version of a motion detector. As the encoder rotates, its angular position is measured and displayed as a graph of angular position vs. time. In constructing the angular position vs. time graph, the orientation of the encoder when the *LabPro* first begins collecting data always serves as the origin of the coordinate system.

I. Constant Angular Velocity

A. Angular Position vs. Time Graphs

Open the file *Rotation.*

Collect angular position vs. time graphs for the following three motions:

- Rotating clockwise
- Rotating clockwise at a greater angular speed
- Rotating counterclockwise

To collect data, press the **Collect** button, wait for the encoder to begin collecting data, and then give the encoder a quick spin. If the data is clean, select **Experiment/Store Latest Run**. If the data is noisy, diagnose the problem and repeat the observation until the problem is solved.

Once you've prepared your graph for presentation, print your graph and attach it to the end of this activity.

Question: Clearly explain how the direction of rotation of the encoder can be determined from an angular position vs. time graph.

Question: Clearly explain how the angular velocity of the encoder can be determined from an angular position vs. time graph.

B. Angular Velocity vs. Time Graphs

Display a graph of angular velocity vs. time.

Question: Clearly explain how the direction of rotation of the encoder can be determined from an angular velocity vs. time graph.

C. Angular Acceleration vs. Time Graphs

Display a graph of angular acceleration vs. time.

Question: In all three trials, the angular acceleration of the encoder should be approximately constant and close to zero after you release it. Clearly explain both why the angular acceleration is constant and why its magnitude is close to zero.

II. Angular Acceleration

Display angular position, velocity, and acceleration graphs.

Hang 10 g from the end of a string wrapped around the encoder. Wrap the string so that the encoder will rotate in the positive direction, and place a small piece of tape on the end of the string so that the string won't slip off the encoder. Press **Collect**, and then release the mass.

If the data is clean, select **Experiment/Store Latest Run**. If the data is noisy, diagnose the problem and repeat the observation until the problem is solved. Replace the 10 g with 20 g and repeat the data collection.

Once you've prepared your graph for presentation, print your graph and attach it to the end of this activity.

Question: Clearly explain how to determine the angular acceleration of the encoder based *only* on an angular position vs. time graph. Perform this analysis and record the results in the table below.

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Trial	Angular Acceleration (rad/s^2) determined from:		
	vs. t	**vs. t**	**vs. t**
10 g	±	±	±
20 g	±	±	±

Question: Are the three quantities measured above consistent, within measured uncertainties, for each motion analyzed?

III. Unbalanced Forces and Torques

Display only an angular acceleration vs. time graph.

In the previous experiment, you measured the angular acceleration of the encoder when an unbalanced torque acted on the encoder. In this activity, you will apply the same unbalanced torque to a slightly different system.

Question: Imagine hanging identical 100 g masses from opposite ends of a string passing over the encoder, and then placing an additional 10 g on one side of the string. If the system is released from rest, will the angular acceleration be greater than, less than, or approximately the same as it was when the two sides of the pulley were unbalanced by 10 g above? Explain.

Perform the experiment described above, and measure the resulting angular acceleration. Record your result and complete the table below.

Hanging Masses	Angular Acceleration (rad/s^2)
0 g and 10 g	±
100 g and 110 g	±
200 g and 210 g	±

Question: Although the difference in mass on the two sides of the pulley is equal in all three trials, clearly describe why the resulting angular acceleration is not the same in all three trials.

III. More with Unbalanced Forces and Torques

A. Relating the Outer and Inner Pulley Radii

In this activity, you will flip the encoder around to use the 3-step pulley.

Hang 10 g from the end of a string wrapped around the outer radius pulley. Hang 20 g from the end of a second string wrapped the opposite direction around the inner radius pulley. Secure both strings to the pulley with small pieces of tape.

Press **Collect**, and then release the masses.

Question: Clearly explain how it is possible for a falling 10 g mass to lift a 20 g mass.

Record your result and complete the table below.

Inner Pulley Mass (g)	Angular Acceleration (rad/s^2)
20 g	±
30 g	±
40 g	±
50 g	±

Create a graph of angular acceleration, with error bars, vs. inner pulley mass. Select an appropriate best-fit function and display it on your graph.

Finish preparing your graph, then print and attach it to the end of this activity.

Question: Based on your best-fit function, determine the ratio of the outer radius to the inner radius (R_{outer}/R_{inner}) of the pulley. Describe how you determined this ratio, as well as how you determined the uncertainty in this ratio.

B. Relating the Outer and Middle Pulley Radii

Determine the ratio of the outer radius to the middle radius (R_{outer}/R_{middle}) of the pulley by collecting and analyzing the following data. In all cases, attach 10 g to the outer radius.

Middle Pulley Mass (g)	Angular Acceleration (rad/s^2)
10 g	±
20 g	±
30 g	±
40 g	±

Create a graph of angular acceleration, with error bars, vs. middle pulley mass. Select an appropriate best-fit function and display it on your graph.

Finish preparing your graph, then print and attach it to the end of this activity.

Question: Based on your best-fit function, determine the ratio of the outer radius to the middle radius (R_{outer}/R_{middle}) of the pulley. Describe how you determined this ratio, as well as how you determined the uncertainty in this ratio.