5.12: Circular Motion

Name: ____

Date: ______________________

Partners:____

Equipment

• *Circle* movie • *Cyclops* movie • *PirateShip* movie • *LabPro* Interface • Motion detector	• Force sensor • *Movie* software file • *Force* software file • Dynamics track • Pulley • Hanging masses

Introduction

It is quite common for objects to move along circular or semi-circular paths. Although these motions can be analyzed using a traditional xy-coordinate system, other coordinate systems, such as polar coordinates, and other sets of kinematic variables (angular variables rather than linear variables) are quite useful. In this activity, the relationships between x- and y-position and velocity to radial and tangential position and velocity, as well as angular position and velocity, will be explored.

I. Circular Motion

Open *Movie* and select **Insert/Movie**. Find the movie *Circle* and open it. Play the movie.

The movie shows a piece of tape with five equally-spaced dots attached to a rotating platform. The central dot is at the center of the platform. Return the movie to the first frame.

Extract position vs. time data for the outermost dot. This dot is 12 cm from the center of the platform. Scale the movie, move your coordinate system to the center of the platform, and rotate your coordinate system so that the initial angular position of the dot is zero.

A. X-Position, Y-Position and Radial Position

Create a graph of x- and y-position vs. time.

Using **Data/New Calculated Column**, create a new column for the radial position (the position in polar coordinates) of the dot. Add the radial position to your graph of x- and y-position vs. time and print and attach your graph to the end of the activity.

Question: Describe your graph. Do the x, y, and radial positions look as you expect?

B. X-Velocity, Y-Velocity, and Tangential Velocity

Create a graph of x- and y-velocity vs. time. Using **Data/New Calculated Column**, create a new column for the tangential velocity (the velocity in polar coordinates) of the dot. Add the tangential velocity to your graph and print and attach your graph to the end of the activity.

Question: Describe your graph. Do the x, y, and tangential velocities look as you expect?

C. X- Position, X-Velocity, and X-Acceleration

Create a graph of x-position, x-velocity, and x-acceleration vs. time. (Use **Data/New Calculated Column**, to create x-acceleration.) Print and attach your graph to the end of the activity.

Question: Describe your graph. Do the x-position, x-velocity, and x-acceleration look as you expect?

D. Angular Position, Angular Velocity, and Angular Acceleration

Create a graph of angular position, angular velocity, and angular acceleration vs. time. (You must first create these columns.) Print and attach your graph to the end of the activity.

Question: Describe your graph. Do the angular position, angular velocity, and angular acceleration look as you expect?

E. Circular Motion with Different Radius

Extract additional position vs. time data, this time for the dot 6 cm from the center.

Question: Carefully explain how the x- and y-position data for the dot 6 cm from the center compares to the same data for the dot 12 cm from the center.

Question: Carefully explain how the x- and y-velocity data for the dot 6 cm from the center compares to the same data for the dot 12 cm from the center.

Question: Carefully explain how the angular kinematic data for the dot 6 cm from the center compares to the same data for the dot 12 cm from the center. **II. Force and Circular Motion**

Open the file *Force.*

Set the force sensor to the ±10 N setting, and calibrate the force sensor with a 200 g mass.

Create a pendulum by attaching a string to the force sensor, passing the string over a pulley, and attaching a 200 g mass to the end of the string. Adjust the endstop of the track to hold the force sensor at rest. You should be able to oscillate the mass back and forth without the force sensor moving. Orient a motion detector to measure the position of the oscillating mass.

Collect data for one complete cycle of the motion. Create graphs of position, velocity, and force vs. time. Print these graphs on the same page. With a vertical line, designate the time(s) at which the mass passes through the equilibrium position.

Question: Clearly explain why the force exerted by the string on the mass is greater than the weight of the mass when the mass passes through equilibrium.

Question: Clearly explain why the force exerted by the string on the mass is less than the weight of the mass when the mass momentarily stops at each end of its swing.

Question: Draw a free-body diagram for the mass as it passes through equilibrium, apply Newton's Second Law, and calculate the theoretical value for the force exerted by the string. Compare this value to the value measured by the force probe. Comment on the agreement between these two values.

Question: Draw a free-body diagram for the mass as it momentarily stops at the end of one swing, apply Newton's Second Law, and calculate the theoretical value for the force exerted by the string. Compare this value to the value measured by the force probe. Comment on the agreement between these two values.

III. The Cyclops

Open the movie *Cyclops.* Play the movie. The movie shows the Cyclops ride at Hershey Park amusement park. The diameter of the wheel, ***not including the cars***, is 17 m.

Although you probably can't recognize me, I'm riding the Cyclops while sitting on a bathroom scale. My mass when the movie was made was 82 kg.

Scale the movie and extract position vs. time data for my motion. Click on where the bathroom scale would be (if you could see it). Notice that I'm upside down at the top of the ride.

To answer the following two questions, fit the appropriate function to the appropriate portion of the data. Print each graph you use with the region selected and best-fit function displayed and attach it to the end of this activity. Show your work in answering each question.

Question: Based on your data, what does the bathroom scale read, with uncertainty and units, at the bottom of the ride's motion?

Question: Based on your data, what does the bathroom scale read, with uncertainty and units, at the top of the ride's motion?

Question: Comment on the effectiveness of your analysis. What could you have done to improve your analysis? Do you feel your results are accurate?

IV. Pirate Ship

Open the movie *PirateShip.* Play the movie. The movie shows the Pirate Ship at Hershey Park amusement park. The people riding the Pirate Ship move along a circular path of radius 20 feet.

Although you probably can't recognize me, I'm riding in the bow of the Pirate Ship while sitting on a bathroom scale. My mass when the movie was made was 82 kg.

Scale the movie and extract position vs. time data for my motion. Click on where the bathroom scale would be (if you could see it).

To answer the following question, fit the appropriate function to the appropriate portion of the data. Print each graph you use with the region selected and best-fit function displayed and attach it to the end of this activity. Show your work in answering the question.

Question: Based on your data, what does the scale read, with uncertainty and units, as I pass through the lowest point on the final swing?

Question: Does my maximum speed occur at the lowest point of my motion? Carefully explain why or why not.

Question: Comment on the effectiveness of your analysis. What could you have done to improve your analysis? Do you feel your results are accurate?