Physics Lab 9: Angular Motion

Goals: Improve communication and teamwork capacities**;** Improve ability to make careful measurements; Use a rotary motion sensor to measure angular position and angular velocity; Investigate the connection between circular motion and linear motion.

Equipment: You will be oriented to the location and proper use of the equipment for this lab. At the end of the session, return the equipment to its original configuration and location.

Groups & Lab Notebook: You will work in groups of 2. Update your Table of Contents. General Lab Notes guidelines apply.

References: Physics Ch. 6.1, Pre-calculus Ch. 5.2, Rotary Motion Sensor User Guide (available in program share: Handouts: Week 6 Lab)

Today, you will learn to use a new kind of sensor: a Rotary Motion Sensor (RMS). The RMS measures ***angular position*** vs. time, and calculates ***angular velocity*** from the angular position vs. time results. This allows you to make measurements related to ***angular*** (or ***circular***) ***motion***. By coupling the motion of a tumble buggy (which moves with constant linear speed) to the RMS, you will also be able to investigate the connection between linear speed and angular speed.

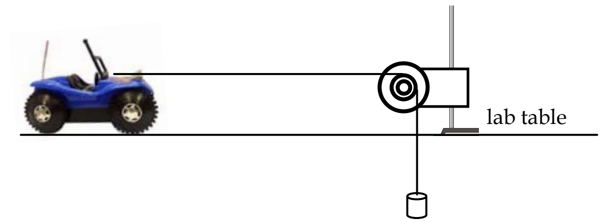
Part 1: Angular Motion

a) After the equipment orientation and introduction, obtain a Rotary Motion Sensor (RMS).
b) Attach the 3-step pulley and the aluminum disk using the mounting screw.
c) Connect the RMS to a LabQuest. Note: the RMS attaches via one of the analog ports, not DIG/SONIC.
d) Launch LoggerPro. You should see two graphs: an Angle (rad) vs. Time (s) graph, and a Velocity (rad/s) vs. Time graph. Note that it might be more clear if the second graph were labeled an Angular Velocity (rad/s) vs. Time (s) graph; you can change that label if you wish – if you can't figure it out on your own, ask for assistance.
e) Start collecting data, and turn the disk clockwise and counterclockwise to determine which direction is positive and negative as measured by the RMS. No need to save this.
f) The following are calculations, not measurements. Using the conversion factor 1 rev = $360^o = 2\pi$ (rad), determine the angular displacement (in degrees and in rad – get both in terms of π and as a decimal equivalent; only keep 2 or 3 decimal places) for a quarter revolution, a half revolution, a full revolution, and 1.5 revolutions, and record these in your notebook. In your notebook, show at least one full calculation including conversion factors. Organize your results into a table.
g) Collect data for the following motion: Rotate the disk a quarter revolution in the positive direction and hold fixed for about 0.5 seconds. Continue to a half revolution, and hold fixed for about 0.5 seconds. Continue to a full revolution (hold fixed for about 0.5 seconds), then continue to 1.5 revolutions and hold fixed for about 0.5 s. Save this with a useful file name.
h) Compare your graph results from g) to the numbers you calculated in f).
i) You may want to practice the following before collecting data. Change the data collection time as needed. Your goal is to obtain angular position vs. time data for the following motion of the disk: 2 full positive rotations at approximately constant angular speed that take approximately 4 seconds; Pause for approximately 0.5 seconds; 1 full negative rotation at approximately constant angular speed that takes approximately 4 seconds; Pause for approximately 0.5 seconds; 2 full negative rotations at approximately constant angular speed that take approximately 3 seconds; Pause for approximately 1 second; 4 full positive rotations at approximately constant angular speed that take approximately 2 seconds; Pause till end. Obtain this angular position vs. time graph. Save with a useful name.
j) You may want to practice the following before collecting data. Hold the RMS so that the disk is oriented horizontally. Spin the disk so that it spins freely, slowing to a stop on its own (due to friction). Note: if you spin the disk too fast, the sensor might not be able to properly measure its angular position at first; that's not a big problem though you might want to adjust the initial spin speed so you can get all the motion in your data run. Change the data collection time as needed. In a single run, obtain data for spinning the disk in the positive direction, slowing to a stop on its own, stopped for approximately 0.5 seconds, then spinning the disk in the negative direction, slowing to a stop on its own, stopped until end. Save with a useful name.

Part 2: Linear and Angular Motion

a) Your goal is to obtain 6 angular position vs. time graphs and 2 linear position vs. time graphs, as described below. One set will be for a tumble buggy with one battery, and attached to the RMS for each of the 3 pulley diameters. You will also obtain the linear position vs. time for the one battery tumble buggy. The other set will be for the tumble buggy with two batteries, also attached to the RMS for the 3 pulley diameters.

b) Gather and assemble your equipment as in the figure. You will only use the 3-axis pulley and not the aluminum disk. Note that the main reason for the hanging mass is to maintain tension in the string so that the linear motion of the buggy turns the pulley. Therefore the hanging mass does not need to be very large; just the mass hangar itself should do. The figure shows the buggy moving towards the sensor; you may find it works better to have your buggy move away from the sensor. However, you should make sure to adjust so that the string attached to the buggy is as horizontal as you can make it.



c) Draw a sketch of your experimental setup in your notebook (it can look very similar to the figure above).

d) As usual, you may want to practice before collecting data. Start with one battery, and have the string go over the large diameter pulley. Obtain good position vs. time data, and rename your best run as 'oneBatteryLargeDiameter'.

e) Repeat for the medium diameter and small diameter pulley, renaming the best runs as 'oneBatteryMediumDiameter' and 'oneBatterySmallDiameter'.

f) Use the Motion Detector to obtain a linear position vs. time graph for the buggy, still attached to the mass. Rename the best run as 'oneBatteryLinear'.

g) Repeat, but this time with 2 batteries, to obtain 'twoBatteryLargeDiameter', 'twoBatteryMediumDiameter', and 'twoBatterySmallDiameter' and 'twoBatteryLinear'.

Analysis Complete as much of the analysis during the lab period as you can. Complete any remaining as homework. If you are analyzing data by yourself, make sure to copy the LoggerPro files from the shared Workspace folder to your own Cubbie.

a) For each step below, adjust your graphs to show individual data points and zoom in so that the interesting data fills the graph.

b) In Part 1 step i), you obtained an angular motion data for: 2 full positive rotations at approximately constant angular speed that take approximately 4 seconds; 1 full negative rotation at approximately constant angular speed that takes approximately 4 seconds; 2 full negative rotations at approximately constant angular speed that take approximately 3 seconds; 4 full positive rotations at approximately constant angular speed that take approximately 2 seconds. For each of these, calculate the angular velocity in rotations (or revolutions per second), degrees per second, and radians per second (in terms of π and the decimal equivalent). Note whether the angular velocity is positive or negative by the sign of your answer.

c) Now, examine the LoggerPro file for this data. By fitting a line to the appropriate region of the angular position vs. time graph and by doing statistics on the same region on the (angular) velocity vs. time graph, find the angular velocity for each part of the motion. Are the two results (from the linear fit and the statistical analysis) consistent with each other for each part of the motion? How well do they match the results of your calculations in the previous step? Save this graph.

d) Organize this work in a table, with columns that describe each part of the motion in words, your calculated angular velocity, the angular velocity from the angular position vs. time graph, and the angular velocity from the (angular) velocity vs. time graph.

e) In Part 1 step j), you started the disk spinning and let it slow down solely due to friction. If you assume the acceleration while the disk is slowing down is constant, what shape (what pattern) would you expect the angular position vs. time graph to be? The (angular) velocity vs. time graph?

f) Look at your associated LoggerPro file. Does it match your response to the previous question? Find the (angular) acceleration by fitting a quadratic to the appropriate part of the angular position vs. time graph and by fitting a line to the appropriate part of the (angular) velocity vs. time graph.

g) For the one battery buggy measurements in Part 2, find the velocity of the tumble buggy by fitting a line to the appropriate region of the appropriate graph. Also find the (angular) velocity for the large diameter, medium diameter, and small diameter case.

h) Use the relationship $v = r\omega$ to find the radius of each of the 3 pulleys.

i) Repeat using the two battery measurements.

j) Are the results for the radii for the large diameter, medium diameter, and small diameter pulleys consist in the one battery vs. two battery case?

k) Compare your results to the manufacturer's reported pulley diameters, which you can find in the RMS User Guide (see References above).