Introduction

The purpose of this lab is to help you understand angular velocity and angular acceleration. In this lab you will be dealing with rotation about a fixed axle, so some of the complexity associated with these quantities will be avoided. The experiments and the analysis of the data will give you another concrete example of the limiting process you are becoming familiar with in calculus.

The Apparatus

You will have a disk mounted on an axle that can rotate almost without friction. A string is draped around the disk and a small weight is suspended from one end of the string.

When the weight is released the disk rotates. The key to the experiment is a sensor that can measure and record the angular position of a point on the disk for a large number of times that are extremely close together. The time interval between measurements is fixed by the apparatus. From this data, which you should call $\theta(t)$, you will be able to calculate $\omega(t)$, the angular velocity as a function of time, and $\alpha(t)$, the angular acceleration, which should be constant. You should make two runs with different weights so that the disk has different angular accelerations. The acceleration of the falling weight should be proportional to the angular acceleration of the disk and this can be verified by timing the fall of the weight through a measured distance. As the disk actually consists of two disks of different radii joined at their centers, you might repeat the experiments, if time permits, placing the string on the smaller disk rather than the larger one.
Procedure

Your lab instructor will show you how to set up the rotation sensor and computer so that you can take and record measurements of the disk's angular position. Once you know how to do this you are to carry out two experiments with different weights. For each one you should obtain a large number of values of $\theta(t)$ which you need to store along with the values of $t$ in an Excel spreadsheet so that you can later analyze the data. The steps you should follow are:

1. To record the data you click on the Logger Pro icon on your computer. Go to File, Open then go to Probes and Sensors, Rotary Motion Sensor, Vernier-Pasco, and finally Rotary High DG1. You just hit the Collect button on the screen and then release the hanging weight and the data is automatically recorded. To change the length of time that data is taken go to Sampling which is also Ctrl+M and then Experiment Length. One may change axes by going to Graph Options and then Axis Options.

2. Go to the Window menu, choose Table and select tall. Determine from the graph the times when the motion starts and stops. In the table select the time and $\theta$ columns from the starting time down to the point where the motion stops. Copy this information by using Control c.

3. Open EXCEL and paste using Control v the data into the Excel spreadsheet.

4. Choose the CHART WIZARD which looks like a bar graph. Select XY scatter plot. For the range choose the $\theta$ data, which should be in the second column. Select the SERIES tab and put in the time, which should be in the first column, as the horizontal values (here called by Excel x even though its the time!) Then hit FINISH.

5. Click on the graph and then select the Chart menu. Go to Trendlines. For the Type select Polynomial and for Order put in 2. Click on Options and select Display Equation on Chart. You should now have the function $\theta(t)$ that has been the object of so much attention in the lectures.

Analysis of Data

Given the polynomial fit to the data you should calculate the derivative of $\theta(t)$ using the rules for differentiation. You then have the angular velocity as a function of time. The goal is to verify that you can get the velocity at any particular time by doing the limit
process. Choose a time early in the range of \( t \) and call it \( t_1 \). We want \( t_2 \) to be a later time at which \( \theta(t) \) was recorded. Therefore let

\[ t_2 = t_1 + \Delta t. \]

There was a certain time interval between data points determined by the apparatus. Let us call this time interval \( z \). Then we can write

\[ \Delta t = nz \]

where \( n \) is the number of intervals between \( t_1 \) and \( t_2 \). (Now by changing the integer \( n \) we can change the size of \( \Delta t \).) From the column of \( \theta(t) \) in the spreadsheet, calculate

\[ \frac{\theta(t_2) - \theta(t_1)}{t_2 - t_1} \]

with

\[ t_2 = t_1 + nz \]

for \( n \) decreasing from some large number to 1. What you are calculating is

\[ \frac{\theta(t_1 + nz) - \theta(t_1)}{t_1 + nz - t_1} = \frac{\theta(t_1 + nz) - \theta(t_1)}{nz} \]

and the limit as \( n \) goes to a small number is the limit as \( \Delta t \) goes to zero. Plot the results as a function of \( n \). If everything works as it should, in the limit of \( \Delta t \) approaching zero the value for \( \omega(t_t) \) should be the same as what you get by putting \( t = t_1 \) in the function \( \omega(t) \) obtained by taking the derivative of \( \theta(t) \). You might repeat this process for a few values of \( t_1 \).

Repeat this process for the other set of data with the different hanging weight.

**Checking the Acceleration**

The acceleration of the hanging weight should be proportional to the angular acceleration of the disk. Using the polynomial fit and differentiating twice you should calculate the experimental value of the angular acceleration. With a timer and a ruler you can measure and the time it takes for the weight to travel a known distance and from this calculate its acceleration. You should verify that for both sets of data, \( a = R\alpha \) where \( R \) is the radius of the disk.