Experiment 1

Determining Angular Acceleration

The purpose of this experiment is to take data for a simple angular acceleration calculation in order to become acquainted with the data analysis techniques you will be expected to use for the remainder of this course. It is very important that you understand that "error analysis" is not merely a listing of potential sources of error with no discussion of their potential impact. Rather, error analysis includes numerical analysis of data and inclusion of known uncertainties to determine numerical values for uncertainties in your calculated results. *Every calculated result in this course should be accompanied by a numerical uncertainty that is well supported by your analysis.* Some procedures for determining these uncertainties can be quite sophisticated. What is presented here is a very basic approach designed to give you the correct order of magnitude of the uncertainty in an intuitively straightforward way. If you have learned more sophisticated methods of error analysis, you are free to use them in place of this simplified approach.

Error analysis may also include approximate corrections for known miscalibrations of equipment or known deficiencies in the theory used to analyze the data. These issues are not addressed in this exercise.

Apparatus

Pasco Rotational Dynamics Platform

As configured for this experiment, this device consists of a heavy black metal base with a freely rotating vertical metal rod. Attached to the rotating rod is a horizontal metal platform (it looks like a fancy ruler). You will also need a stopwatch.

Procedure

1. There are 2 adjustable weights mounted on the top of the horizontal rotating platform. One may have coins taped to it. Do not remove the coins since they are present to balance the weights. The weights should be centered at about 15 cm on either side of the middle of the rod. This distance is not critical; just make sure the screws securing these weights are tight enough that the weights do not slide around (but do not over tighten them so that they are impossible to loosen!).

2. Directly underneath the rotating platform, mounted on the vertical rotating rod, you will see three pulleys ("platform pulleys"). There should be a black thread tied to that system of pulleys. Wind the thread around the lowest platform pulley (the largest of the three), and drape the free end of the thread over the other pulley (the "guide pulley") that hangs over the edge of the table. Hook a 50 g mass onto the free end of the string. When released, the hanging weight pulls on the string that in turn applies a torque to the pulley, causing the rotating platform to undergo angular acceleration. You will measure this acceleration.

3. Line the rotating platform up with the horizontal rod on which the guide pulley is mounted. Release the platform from rest at the same time you start the stopwatch. Stop the watch when one full revolution has been completed. Record this time on the chart and repeat until you have five complete measurements. In between each measurement, rewind the thread, being careful that it stays on the bottom platform pulley. (It sometimes has a tendency to rewind on an upper platform pulley.)

4. Repeat step 3 but allow the platform to rotate 2 full revolutions (after starting from rest).

5. Repeat step 3 for 3, 4 and 5 full revolutions. Make sure when you get out to 5 revolutions that the hanging mass is still descending at the end of the timing interval. If it is already on its return, then the thread is too short and you will need to cut a new one.

6. Estimate the uncertainty in your determination of the number of revolutions. That is, when you visually determine that the arm as rotated 360°, how close do you think your visual determination is to what actually takes place? Are you within 0.1°? 1°? 10°? While this is probably easier to estimate in degrees, convert your final answer to radians, being careful not to add on extraneous "significant digits" in the conversion process. That is, 1°=0.02rad, not 0.017453rad.

Data analysis:

We expect the time it takes to complete a given number of revolutions to be identical (even though our manual timing of the interval yields different results). Thus it makes sense to average this data. Compute an average and enter the result in the appropriate column on the chart. Next identify the minimum and maximum time value in each data set. Lastly, express the average and uncertainty in such a way that all of your data points are included in your uncertainty interval. For instance, if I have five time measurements, 2.1s, 2.3s, 2.8s, 2.2s, 2.7s, then I would express the average and uncertainty as 2.4 +/- 0.4 s. The average is 2.4s and all the data lies within the interval of 2.0s to 2.8s. Note: if we had a larger data set (say a hundred measurements), we would calculate the statistical variance in the data rather than looking for the maximum and minimum value.

First method for determining the acceleration:

Calculate the angular displacement corresponding to 5 revolutions, expressing your answer in radians. Record this number on Chart 2 along with the uncertainty you estimated in step 6 above. For a rotating object undergoing constant angular acceleration and starting from rest,

$$\theta = \frac{1}{2}\alpha t^2 \qquad (1.1)$$
$$\alpha = \frac{2\theta}{t^2}$$

Use this result to determine the best estimate of the angular acceleration, α, by inserting the best values for θ and t from your 5 revolution data. Next, determine the smallest value of α possible, given your data. This is done by inserting the minimum value of θ and the maximum value of t. Finally, determine the largest value of a by inserting the largest value of θ possible and the smallest value of t possible. Now you can complete this portion of the chart by expressing the range of possible values of α in the form of a number +/- an uncertainty (e.g., 2.5+/-0.1)

We can obtain a similar (but not identical) result for the uncertainty interval if we assume that the data taken has a normal distribution about the true value. The uncertainties can then be combined using the techniques described in the PHY 223/224 lab manuals. In particular, for a function, f, of the form

$$f = Ax^n y^m,$$

where x and y have uncertainties δx and δy respectively, the uncertainty in f is given by

$$\delta f = f\left[\left(n\frac{\delta x}{x}\right)^2 + \left(m\frac{\delta y}{y}\right)^2\right]^{1/2}. \qquad (1.2)$$

Applying this relation to the equation for α gives

$$\delta\alpha = \frac{2\theta}{t^2}\left[\left(\frac{\delta\theta}{\theta}\right)^2 + \left(\frac{2\delta t}{t}\right)^2\right]^{1/2} \qquad (1.3)$$

Enter this value in the last spot on the chart. The value should be the same order of magnitude as the uncertainty determined by the previous approach. You are free to use either method to calculate uncertainty in this course since the objective is to develop an intuitive understanding of uncertainty. While the second approach is preferred when there is a large quantity of data to analyze, it is not clear if it conveys more useful information than the first approach when only a few data points are involved.

Second method for determining the angular acceleration:

This method requires the use of a spreadsheet such as Microsoft Excel. This software is available on library computers. If you do not know how to perform any of these operations, please see me as soon as possible. It is straightforward to learn and you will likely find spreadsheets useful throughout your physics career.

Enter the five average times (from your chart, without uncertainties) into a column on the spreadsheet. Next to each of these values, have the spreadsheet calculate the square of the time. In the column next to the square of the times, enter the displacements (in radians). Now have a scatter plot drawn of the data in the last two columns. Plot just the points—do not yet show a line through the data. Comparison to equation (1.1) shows that the slope of the plot of θ vs. t^2 will equal $\alpha/2$. If you are able to do so with your spreadsheet program, have these points fit by a straight line subject to the constraint that it passes through the origin. In Excel, this can be done by opening the chart menu and selecting Add Trendline. When you add the trendline, be sure to select options and specify that the origin is included in the trendline ("set intercept=0") and have it display the equation. Label axes as appropriate and print your graph when you are done. Double the slope on the trendline and compare to the angular acceleration you determined by the previous method.

For this lab, you need only turn in your chart and the plot.

Your name:

Partner's name:

	1 rev	2 rev	3 rev	4 rev	5 rev
Trial 1					
Trial 2					
Trial 3					
Trial 4					
Trial 5					
Average time					
Uncertainty (+/-)					
Angular Displacement +/- uncertainty (rad)					
α (best value)	X	X	X	X	
α (min value)	X	X	X	X	
α (max value)	X	X	X	X	
α +/- uncertainty	X	X	X	X	
Uncertainty using eq. (1.3)	X	X	X	X	

Acceleration as determined by the graph: