Physics 122 - Lab 7

Goal: To understand torque, angular acceleration and energy conservation in angular motion.

Equipment: Vertical frictionless axis, frictionless pulley, massless non-stretchable string, motion detector.

Procedure

1. Weigh the red plastic tray at the front of the room, including the associated hardware used to attach it to the string. Weigh the gray plastic tray, and all the components that are used in the rotating setup disassembled at the front of the room. Measure their masses and dimensions so that you will be able to calculate the relevant moment of inertias, and calculate the total moment of inertia of the rotating system.

2. Measure and record the axis diameter where the string is wrapped around it. Choose a mass (record its value) and place it in the red plastic tray. Make sure that the string passes over the pulley. Make sure that the string will unwind from the axis without slipping (use a tape to fix the initial round from sliding down). Release the mass from rest and record its position and velocity using the motion detector. Fit v to determine a. Repeat this measurement several times and average the results to find the acceleration.

3. Repeat the measurement in (2) using a different radius axis; just move the string vertically along the axis so that it is wrapped around a spot with different radius. Measure and record this radius. Make sure that the string is perpendicular to the axis and that the string will unwind from the axis without slipping.

4. Change the mass distribution of the plastic tray. <u>Tape</u> a mass to the tray. Record the mass and its distance to the axis of rotation. Repeat the measurement in (2). Tape a second mass to the tray, record its mass and distance to the axis of rotation and repeat the measurement in (2). Remove the first mass and repeat the measurement in (2). Remove the attached masses from the tray.

5. Apply a constant frictional torque to the tray and record position/velocity for the suspended mass. Remember to fit the velocity data to determine the acceleration.

6. <u>Without using tape</u>, place a 500g mass in the tray adjacent to the axel. Repeat the measurement in (2). Place the mass at <u>exactly the same position</u> in the tray for

each ‘run’ (use a marker to label your starting position). Carefully observe the mass in the tray. Now, repeat this experiment starting the mass in the tray at about 1/2 the distance to the rim. Remember to fit v to determine a.

7. If you have time, you may do this part for **‘extra credit’**. Devise a method for determining the <u>friction in the bearings</u> of the ‘frictionless axis’. Determine the friction in these bearings. You may want to discuss your strategy with the instructor and/or TA.

Analysis

(Some of this analysis may be *best* accomplished before you leave the lab!)

1. Calculate I for the rotating system using the masses and dimensions of the gray plastic tray and other components from (1) of the procedure.

2. Draw free body diagrams for the suspended mass and frictionless axis for part (2) of the procedure (assume no friction anywhere, massless and non-stretchable string and massless and frictionless pulley). Using Newton’s laws, find expressions for the acceleration of the suspended mass and angular acceleration of the axis. Use these expressions and the accelerations measured in (2) and (3) of the procedure to find the moment of inertia of the frictionless axis.

3. Using I for the axis without the additional masses and the mass and distance to the axis of rotation for these masses, calculate I of the axis for each of the configurations in (4) of the procedure. Repeat the analysis of (2) to determine I for each configuration. Include your calculations for I for both methods.

4. Draw free body diagrams for the masses you placed on the tray in (6) of the procedure. Determine the acceleration of these masses as long as they are not sliding on the tray. Determine the coefficient of static friction between the 500g mass and the tray.

Questions

1. Using the expressions for a and α found in (2) of the analysis, find v and ω. Compare the v(t) that you found with what you measured in parts (2) and (3) of the procedure by plotting them on the same axes. How well do they agree?

2. Using energy methods, find expressions for v for the suspended mass and ω for the axis. Using the positions and velocities measured in (2) and (3) of the procedure find whether the work–kinetic energy theorem is verified?

3. How does changing the radius of the shaft in (2) and (3) of the procedure affect the relationship between a and α? What did it do to a? Why?

4. How well do the values for the moment of inertia that you calculated in (1) and (2) of the analysis agree? If they differ, why do you think that they do?

5. Draw a free body diagram for the axis including the frictional torque you applied in (5) of the procedure. Using Newton's Laws, solve for the frictional force for each of its values. Using the velocity and position data you acquired, verify that the work done by this frictional torque accounts for the difference in the total mechanical energy of the system when the mass is at the 'top' and 'bottom' of its path. Would it be possible to adjust the frictional torque so that the acceleration of the suspended mass was 0?

6. For part (6) of the procedure, what is the direction of a for the masses you placed in the tray? If the masses slide on the tray, what forces act on them? Could you use Newton's laws to unambiguously determine the acceleration while the masses were sliding? What happens to the acceleration and velocity of the suspended mass once the mass in the tray begins to slide? What's different in the behavior of the mass when you start it at different distances from the axis? What's the same?

7. If you did (7) of the procedure, describe your method. What is the frictional torque?

<u>What you need to turn in</u>

1. The mass and dimensions of the gray tray. Your calculations of its moment of inertia in analysis (1).

2. A table of shaft radius, a & α measured or determined in (2) and (3) of the procedure.

3. The free body diagrams and Newton's laws calculations from analysis (2).

4. A table with shaft radius, m and r for the additional masses for (4) of the procedure. Include both values of I that you determined in (3) of the analysis in your table.

5. The free body diagrams for the masses placed in the tray for part (6) of the procedure.

6. The answers to the questions.

7. The graph produced in question (1).

Including your drawings, free body diagrams and the lab report cover page, your lab report should not be longer than 7 pages. Please include the list of co-workers in your group on the cover page.