Rolling Disk Lab
(L-77)

This lab is designed to give you the opportunity to theoretically evaluate a situation in which a body both translates and rotates (i.e., the body will roll down an incline), then check to see if the theoretical predictions match up to real life.

Procedure:

a.) Make an incline (I may have already set one up in the room, but if I haven't make one of your own) with a meter stick placed along its length. You should also be given a steel cylinder (this is what will roll down the incline). The data you will need from the system will be:

i.) The mass and diameter of the cylinder.

ii.) A video of the cylinder rolling down the incline (hint: I would suggest you have the cylinder placed so that it starts at the zero point of the meter stick—I would also suggest that whoever releases the cylinder for the roll do the release quickly and in a pronounced way so it is obvious when looking at the video exactly when t = 0 is.)

iii.) The angle of the incline.

Calculations:

1.) On the Web site in the folder dedicated to this lab, you should find a document called "data template for rolling disk." Print that out and use it to determine the experimental acceleration of the cylinder's center of mass. Call this a_{exp}.

Explanation: In a nutshell, you need to take your video, transfer it to your computer via email or whatever, open it up in Quick Time and use the "right/left" keys to begin walking the cylinder through the cylinders roll down the incline (how you will take data is explained below). It should be noted that each click will be worth 1/240 of a second (if the video was done in slow motion), so 35 clicks will have taken a time 35/240 of a second. As for data taking:

i.) The average velocity ($\frac{x_2 - x_1}{\Delta t}$) between two points is equal to the instantaneous velocity at the *halfway time point* between those two points. Additionally, calculating an acceleration requires two instantaneous velocities and the time between them ($a = \frac{v_2 - v_1}{\Delta t}$). That means we need to determine two instantaneous velocities from our video. To do that:

ii.) Start with the cylinder's front edge (as best you can tell) at the 10 centimeter mark (we'll call this $x_o = .10$ meters) and click 50 times. That means you will have moved it for 50/240ths of a second (assuming the video is in slow motion, as the video that I've put on-line is). On your data template, record as best you can the position of the front edge of the cylinder at that point in time. Call it x_1.

iii.) Now click another 50 times (this will take the cylinder another 50/240ths of a second down the incline). Record that new position and call it x_2.

iv.) Determine the average velocity between x_o and x_2 (this will be $\frac{x_2 - x_0}{\Delta t_1}$, with $\Delta t_1 = \frac{(50)+(50)}{240} = \frac{100}{240}$ seconds. THIS WILL BE THE VELOCITY AT POSITION X_1 --AT THE HALFWAY TIME POINT OF THE INTERVAL.

v.) From x_2, click another 50 times, identify the position and call it x_3. Then click another 50 times, identify that position and call it x_4. Using the technique outlined above, determine the instantaneous velocity at x_3.

vi.) Knowing that 100/240 seconds reside between x_1 and x_3, and knowing the velocities at those points, you can use $a = \frac{v_3 - v_1}{\Delta t}$ to determine the acceleration of the cylinder as it rolls down the incline.

2.) Noting that the moment of inertia about the center of mass of a cylinder is $\frac{1}{2}MR^2$, where M is the cylinder's mass and R is it's radius, derive a general, algebraic expression for the acceleration of the cylinder's center of mass. (Note that this is going to require using N.S.L. in both translational and rotational mode.) Your final solutions should be in terms of g and θ, where θ is the angle of the incline.

3.) Using the numbers you recorded during lab, use your theoretical expression for the acceleration of the cylinder's center of mass to determine that value for our situation.

4.) Do a % comparison between the theoretically expected and experimentally observed accelerations. Comment.

QUESTION

A.) It is not uncommon to have relatively large % deviations with a lab like this. The why of it is usually not something students can often see, so I'm going to give you a hint. If your theoretical and recalculated accelerations are close, assuming the angle of the incline is ONE DEGREE *less than* you measured. If they are not close, assume ONE DEGREE *more than* you measured. No matter which way you go, how much does a *one degree discrepancy* in the angle matter in the final acceleration value (i.e., does accuracy with the incline angle matter much)?