PHY 123 Lab 6 - Angular Momentum

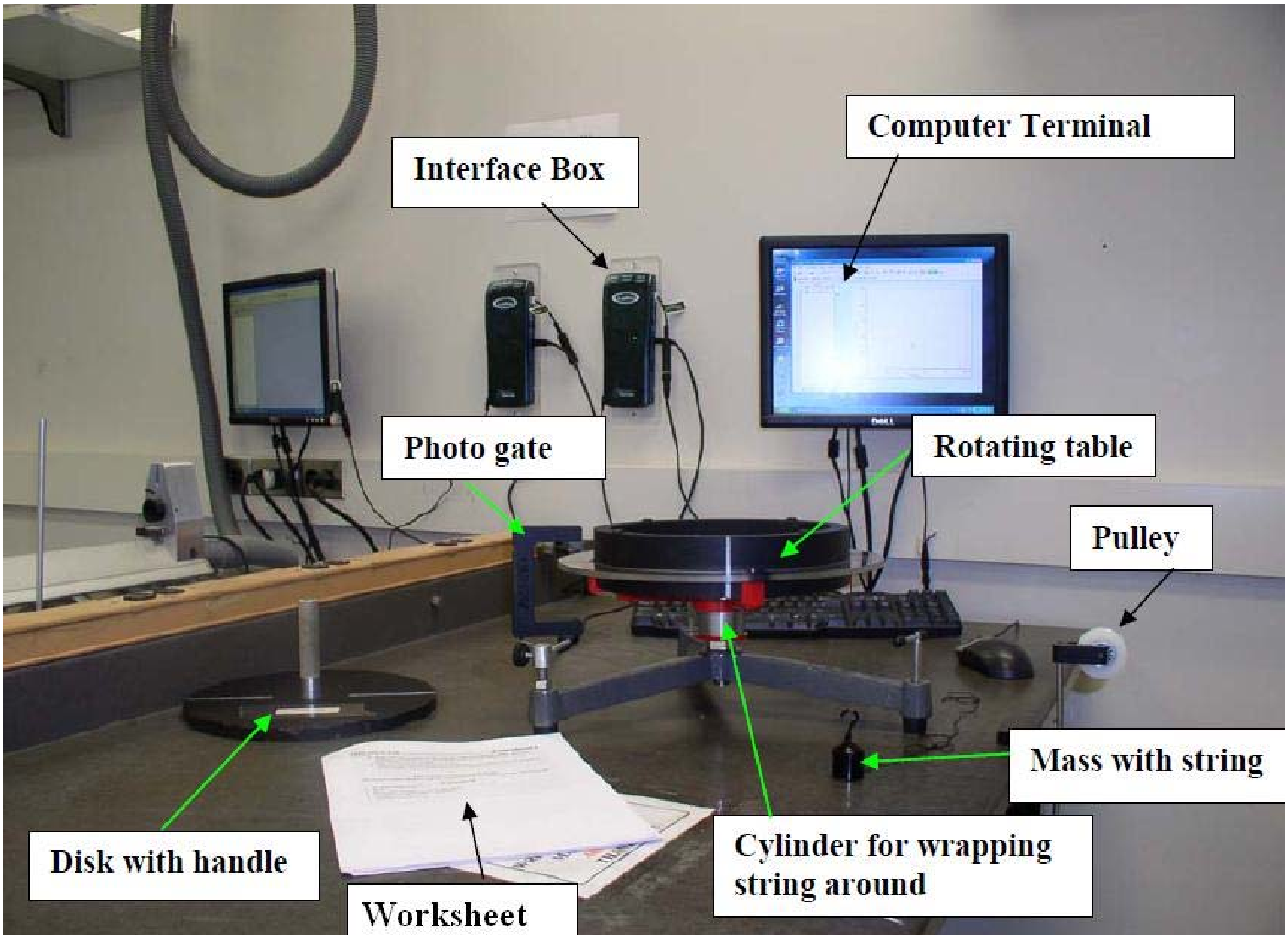
The purpose of this lab is to study torque, moment of inertia, angular acceleration and the conservation of angular momentum.

Important! You need to print out the 3 page worksheet you find by clicking on this link and bring it with you to your lab session. [http://www.ic.sunysb.edu/Class/phy122ps/labs/dokuwiki/pdfs/lab6worksheet.pdf]

If you need the .pdf version of these instructions you can get them here [http://www.ic.sunysb.edu/Class/phy122ps/labs/dokuwiki/pdfs/phy123lab6.pdf].

Equipment

- rotating table with photo gate and pulley , with cylinder for string
- disk with handle
- mass with string attached which winds around cylinder attached to the rotating platform
- interface box
- vernier caliper: to measure the diameter of the cylinder
- computer



Introduction

In Part I we measure the angular acceleration α of an object, a rotating table under a known external torque and obtain its moment of inertia I. The equation which relates the net torque τ_{net} to the moment of inertia and the angular acceleration of a rotating object is

$$\tau_{net} = I\alpha$$
(6.1)

We measure the angular acceleration by measuring the angular velocity ω as a function of time t. For a constant angular acceleration the equation which gives the dependence of ω on t is

$$\omega = \omega_0 + \alpha t$$
(6.2)

In Part II, after the moment of inertia I of the rotating platform has been determined, Conservation of Angular Momentum is investigated. The definition of Angular Momentum L is

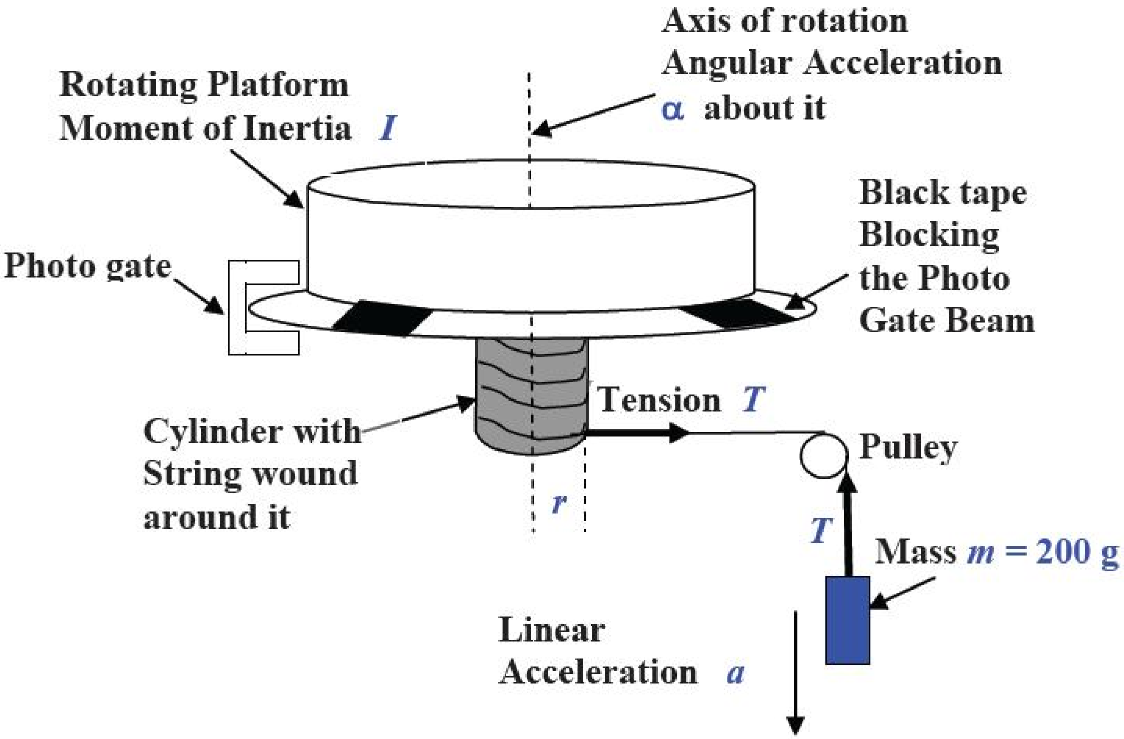
$$L = I\omega$$
(6.3)

We test Conservation of Angular Momentum using the relation

$$I\omega = I'\omega'$$
(6.4)

where the dashed quantities refer to the angular momentum and angular velocity in the final state, and the undashed quantities refer to same things in the initial state. In order to change the moment of inertia of the rotating object we drop a disk (the disk with a handle in our equipment) onto the rotating platform, thus changing the moment of inertia, and measure the angular velocity ω before and after the drop.

Measurement of the Moment of Inertia of the Rotating Platform and Attached Cylinder



The apparatus used for this lab is sketched in Fig. 2 above. A small cylinder with string wound around it is attached to a rotating platform. The tension T due to a weight of mass m attached to the string provides an external torque, τ_{ext}. When the platform rotates a photo gate registers whenever one of the 4 black radial strips on the plastic rim of the platform blocks the light beam of the photo gate. From the 90^{o} angle between the strips the angular velocity ω is computed. The system is not friction free. A frictional torque, τ_{fr} , opposes the external torque thus causing a smaller net torque, $\tau_{net} = \tau_{ext} - \tau_{fr}$. The net torque gives the rotating platform an angular acceleration α which is measured from the rate of increase of the angular velocity. The frictional torque τ_{fr} causes a frictional deceleration α_{fr} .

The moment of inertia I of the rotating platform can be calculated from

$$I = \frac{mr(g - r\alpha)}{|\alpha_{fr}| + \alpha}$$

(6.5)

where g is the acceleration of gravity and r is the radius of the cylinder around which you wind the string(see Fig. 2 above).

Use the vernier caliper to measure the diameter (ask your TA in case you have questions about the caliper scale) of the cylinder under the rotating platform. Apply the caliper to the cylinder, snuggly, and remove it. From the diameter, get the radius r of the cylinder (see Fig. 2 above). Use +/-0.5 mm as your absolute error on the radius r . Enter r and its absolute error Δr on your worksheet.

Make sure your string is long enough to reach from the small cylinder in Fig. 2 (which you wind the string around) to close above the floor, in order to collect enough data points when the weight of the mass m falls toward the floor.

Connect the photo gate output to the interface box by plugging its cable into the top socket (labeled “DIG/SONIC 1”) of the black interface box (“LabPro”).

Turn on the computer and check the system by following these instructions: Double click the icon “Exp6_omega_t”. A window with a spreadsheet on the left (having “Time, Velocity, Status 1 columns) comes up. On top is a window “Sensor Confirmation”.

Click “Connect”, again “Connect”. Test the photo gate: block the photogate beam with your finger and see the red light on the cross bar of the photogate turn on.

Enter your value for the angular distance (90^{o}) from one black tape to the next in radians ($\pi/2$) into the program: Click Data→User Parameters: the window “User Parameters” comes up and should show:

Name:	Value:	Units:	Places:	Increment:	Editable:
PhotogateDistance1	*your value of d*		4	1.0000	✓

Click OK. You are ready for data taking now.

Position the rotating wheel such that the light beam of the photo gate is just to the right or the left of a piece of black tape, making sure that the tape is not obstructing the light beam. You will spin the rotating wheel either clockwise or counterclockwise so that initially the full distance between two pieces of tape sweeps past the photo gate.

Measurement of α_{fr}

Spin the rotating table slowly, click the green “Collect” icon and collect ~ 15 velocity-time pairs of data, then hit STOP. On the screen, you should see a table of values of time t and angular velocity ω and a falling, approximately linear, graph(the S.I.unit for angular velocity is radians/s, ignore the units for linear velocity on your computer screen). If there is a kink in your data, ignore any points before it and copy the first 10 velocity – time pairs after the kink into Table 1 on your worksheet.

Enter the values in Table 1 without any errors in to the plotting tool below. The fit should give you a negative slope for your line, the value of this slope is α_{fr}.

x axis label (include units):

y axis label (include units):

Check this box if the fit should go through (0,0). ☐

(Don't include (0,0) in your list of points below, it will mess up the fit.)

What kind of errors are you entering below? None

x1:		+/-		y1:		+/-	
x2:		+/-		y2:		+/-	
x3:		+/-		y3:		+/-	
x4:		+/-		y4:		+/-	
x5:		+/-		y5:		+/-	
x6:		+/-		y6:		+/-	
x7:		+/-		y7:		+/-	
x8:		+/-		y8:		+/-	
x9:		+/-		y9:		+/-	
x10:		+/-		y10:		+/-	

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Measurement of α

Attach the 200 g mass, m, to the free end of the string and wind the string around the cylinder. Loop the string over the pulley and position the photo gate as you have done above in the measurement of α_{fr}. Click the green “Collect” icon and release the weight. Push “STOP” when the mass is done falling or before the mass touches the floor.

Make sure you have ~15 velocity-time pairs of data collected. Copy the first 10 velocity – time pairs into Table 2 on your worksheet. Make sure the photo gate is oriented such that the light beam is really intercepted by the black tape. Use the plotting tools below to plot your values and obtain the slope as you did in the previous measurement. (The slope of this line should be positive). Enter your slope value, which is α on your worksheet.

x axis label (include units):

y axis label (include units):

Check this box if the fit should go through (0,0). ☐

(Don't include (0,0) in your list of points below, it will mess up the fit.)

What kind of errors are you entering below? None

x1: +/- y1: +/-

x2: +/- y2: +/-

x3: +/- y3: +/-

x4: +/- y4: +/-

x5: +/- y5: +/-

x6: +/- y6: +/-

x7: +/- y7: +/-

x8: +/- y8: +/-

x9: +/- y9: +/-

x10: +/- y10: +/-

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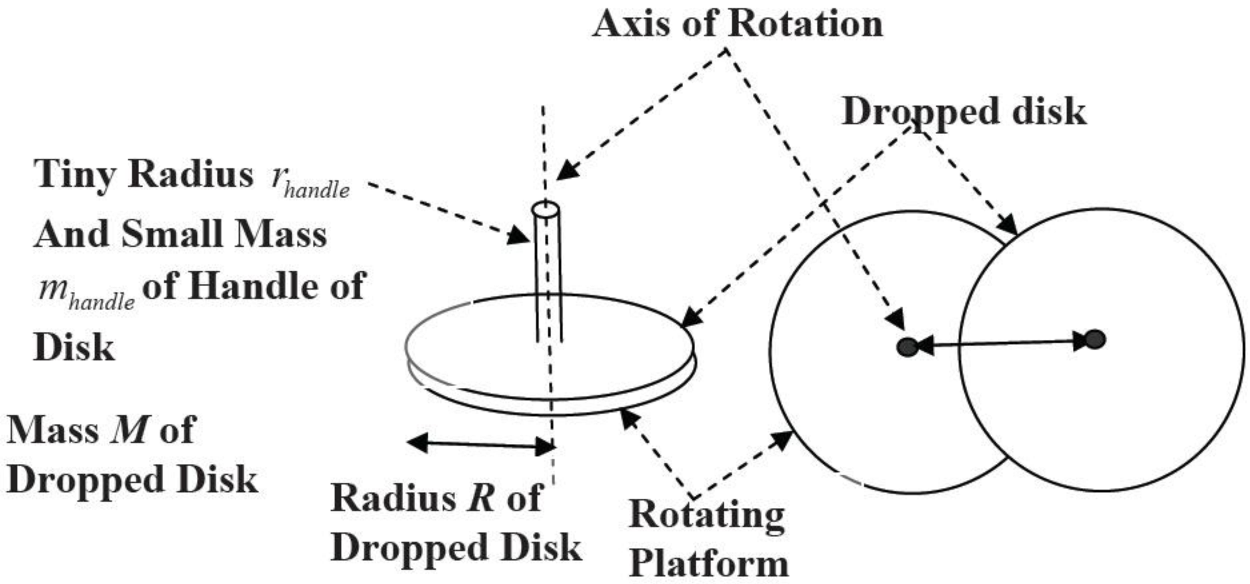
Calculation of I

We have now measured everything we need to calculate the moment of inertia of the system using equation 6.5. The only error we will take into account is the error in r, and we will consider that the relative error in r is the same as the relative error in I.(because g is much greater than $r\alpha$ and the relative error in the mass measurement is very small). Therefore if you multiply your value for I by the relative error in r you can obtain an estimate for the absolute error in I. Write down both your value for I and your estimate for the error in this value on your worksheet.

Testing conservation of angular momentum

Now that we know what the moment of inertia of the system is we will perform an experiment in which we change it by increasing its mass. This is done by dropping an additional disk (see the “disk with handle” in Fig. 1) on top of the rotating platform. This drop (if done carefully) does not cause an external torque which would modify the initial angular momentum.

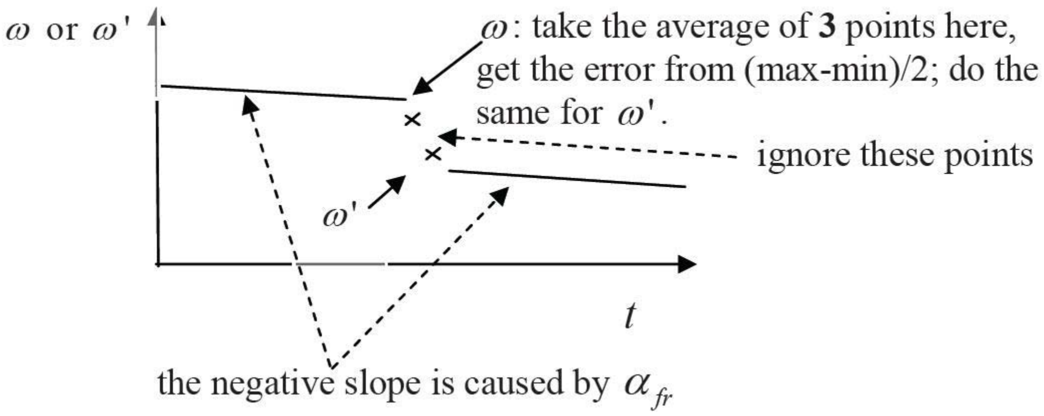


We need to calculate the moment of inertia I_{disk} of the disk with handle from its mass M and its radius R, using the formula.

$$I = \frac{1}{2}MR^2$$
(6.6)

You can neglect the small contribution of the handle on the dropped disk to the moment of inertia. Measure the radius R of the disk with handle (to be dropped), with the ruler and use 1mm for its absolute error. Obtain the value of M and use 1 gram for its error. Enter all values on your worksheet. As before you can assume that the relative error in I is the same as the relative error in R, which you can use to calculate the value of the absolute error in I, ΔI which you should record on you worksheet. The final moment of inertia I' is equal the sum of I and I_{disk}, the moment of inertia of the dropped disk. For the total moment of inertia I' of the combined object (platform + dropped disk) take simply the sum of the two moments of inertia, $I' = I + I_{disk}$. Write your value for I' on your worksheet. This is only valid if the axis of rotation goes through both the center of the rotating table and the center of the dropped disk (When you calculated I_{disk} you used an equation which was valid only if the axis of rotation went through its center). To find the error in I' use equation (1.6) of Lab 1.

Remove the string from the rotating table. Get the computer ready for data taking as you have done previously and then spin the rotating table. Click the green “Collect” icon. Collect some points and, while the rotating table is spinning, drop the disk with handle onto it from a small height (less than 1cm) above the platform. You want the rim of the disk to match the rim of the black cylinder on the platform as closely as possible. You should get a graph that looks roughly like this:



The higher line group corresponds to the initial angular velocity ω and the lower line group corresponds to the final angular velocity ω'. From the spreadsheet on the PC Monitor enter each group of 3 points next to the jump $\omega \to \omega'$ into Table 3 on your worksheet.

Calculate the average value of ω and ω' and use the difference between the maximum and minimum values of ω and ω' as an estimate of the error in these two quantities. Fill these values in on your worksheet.

You are now ready to work out L and L' from equation (6.3). You should also calculate the error in L and L' using equation (1.7). Once we have done this we can see if L and L' are the same within experimental uncertainty. Was angular momentum conserved in your experiment. If it wasn't can you think of possible reasons? For example, if you don't drop the disc right on the center will it make a big difference? Discuss these things with your TA!

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