Walk-in Lab 12
Angular Momentum
Physics 121

CID(s): _______________________

**Description**

Today you get to play with angular momentum using a rotating platform, some weights, and a bicycle wheel. You’ll also get to play with a rotating rod and moving weights. We’ll look at the conservation of angular momentum and also at what happens with the torque is perpendicular to the angular momentum. Don’t get too dizzy! Work together and have a good time. Let me know how things go and email me ideas for making the lab better. Have a great day!

**Objective:** To study angular momentum with and without external torques.

**Equipment:** Rotating platform, dumbbell weights, bicycle wheel, rotating arm with moveable weights.

**Part A – Conservation of Angular Momentum**

For the first part, we’ll look at the conservation of angular momentum. You will find a rotating arm with moveable weights, kind of like this drawing:

The weights have strings tied to them and the strings go through some little loops near the axis of rotation. When you pull up on the strings, the weights will move in, towards the rotation axis. This changes the rotational inertia $I$, but there is no torque. (Do you know why? Think about the formula $\vec{\tau} = \vec{r} \times \vec{F}$.)

Your job is to calculate the moments of inertia when the weights are in the two different positions and to show that the rotation period changes in the right way. Here is some data for you. The stops are placed on the rotating rod so that the masses move from a radius $R$ to $R/2$. The mass of the weights $M$ and the radius $R$ are (hopefully) written somewhere on the experiment. The length of the rod is $L = 2R$ and the mass of the rod is one third the mass of the moveable weights. The total rotational inertia is the sum of the rod and the two weights.

On the back of this sheet, derive and expression for the ratio $I_{\text{out}}/I_{\text{in}}$, where $I_{\text{out}}$ and $I_{\text{in}}$ are the total rotational inertias when the masses are “out” and “in.” Record your result here:

$$I_{\text{out}}/I_{\text{in}} = \text{(1)}$$

The angular momentum is $L = I\omega$, and the period of rotation is $T = 2\pi/\omega$. On the back of this sheet, show that

$$\frac{T_{\text{out}}}{T_{\text{in}}} = \frac{I_{\text{out}}}{I_{\text{in}}}.$$
OK. Now let’s make some measurements. Use the laser/timer setup to measure the rotation period accurately. Since a small amount of the angular momentum is lost due to friction, we have to average the measurements. Start the arm rotating with the weights in the “out” position. Measure $T_{out}$. Pull the string and measure $T_{in}$. Release the strings and measure $T_{out}$ again. Then average the two $T_{out}$ measurements and divide by the $T_{in}$. Write your result here:

\[
\begin{align*}
  \text{first } T_{out} &= \quad \\
  T_{in} &= \\
  \text{second } T_{out} &= \\
  \frac{T_{out,\text{avg}}}{T_{in}} &= 
\end{align*}
\]

(3)

How does your ratio compare to your prediction from Eq. 2?

You can do a similar experiment standing on the rotating platform. Sit on the platform (or stand if you have good balance) and have someone start you spinning slowly. Hold the dumbbell weights and out and in like we did in class and notice how your rotation speed changes. Be careful!

Part B – Vector Angular Momentum

Now let’s think about what happens when you stand on the rotating platform holding a rotating bicycle wheel. I’ve sketched the wheel and a coordinate system in this drawing:

When you apply the force $F_y$ as shown, you will start to rotate counter clockwise around the $y$ axis.

The equation that helps us understand this is

\[
\tau_{\text{external}} = \frac{dL}{dt} \approx \frac{\Delta L}{\Delta t}.
\]

(4)

The angular momentum vector points along the positive $z$ axis. When you apply a force in the negative $y$ direction, the torque is $\tau = \vec{r} \times \vec{F}$. The vector $\vec{r}$ in this case points from the center of the wheel to the place where you apply the force (the handle). So the torque (remember the right-hand rule) points in positive $x$ direction. This means that the tip of the angular momentum vector will move towards the positive $x$ axis and you will start to rotate counter clockwise.

Try this! Get the wheel spinning, hold it in the horizontal position, step carefully onto the rotating platform, and turn the wheel handle.

There are no numbers for this section, but check this box to let me know that you (or some brave person in your group) tried this part.

☐ I (or we) tried this (and survived).