Experiment 7: Rotators

Name:

Partner:

Date:

Purpose

Study angular momentum conservation and rotational kinetic energy in two different situations: a rotational collision and in a race between a slider and a yo-yo.

Equipment

- rotational apparatus
- smart pulley
- signal interface box
- Macintosh computer
- *DataStudio* software
- tilted air table
- large disk
- string
- stop watch
- mass balance
- ruler

Theory

Linear momentum $\vec{p} = m\vec{v}$ and translational kinetic energy $K_{\text{trans}} = \frac{1}{2}mv^2$ characterize the dynamics of a point particle of mass m translating with linear velocity $\vec{v}$. Analogously, angular momentum $\vec{L} = I\vec{\omega}$ and rotational kinetic energy $K_{\text{rot}} = \frac{1}{2}I\omega^2$ characterize the dynamics of an extended rigid body rotating about an axis of symmetry with rotational inertia I and angular velocity $\vec{\omega}$. (Rotational inertia depends on the mass distribution of the body about the rotation axis, and hence is more complicated than translational inertia.)

While the conservation of linear momentum reflects the *homogeneity* of space, the conservation of angular momentum reflects the *isotropy* of space. Homogeneity and isotropy are *symmetries*. Something is *symmetric* if it is *invariant* (that is, it does not change) under a transformation. Something is homogeneous if it is invariant under *translations* and is isotropic (the same in all directions) if it is invariant under *rotations*.

Procedure

1. Rotational Collision
   1.1. Setup
      1.1.1. Mass the auxiliary platter and measure its radius.

M	*R*

      1.1.2. Connect the smart pulley sensor attached to the rotational apparatus to the signal interface box via digital channel 1 and turn on the interface box.
      1.1.3. Create a new experiment in *DataStudio* with a smart pulley. You will want a graph to see the data.

   1.2. Experiment
      1.2.1. Spin the main platter of the rotational apparatus and observe the resulting graph in *DataStudio*. If the graph is wobbly, check that the smart pulley is making good contact with the main platter. Too much or too little contact will cause problems.
      1.2.2. Examine the graph and note the effects of friction — some angular momentum is being transferred to Earth! What causes this friction?

      1.2.3. Hold the auxiliary platter *just* above the main platter and then spin the main platter (this is what partners are for). After recording a few seconds of data, drop the stationary auxiliary platter onto the spinning main platter and record a few more seconds of data.
      1.2.4. Use the *DataStudio* tools to determine the linear velocity of the platters just before and just after the rotational collision and record them in the table below.
      1.2.5. Do the experiment five times with different initial velocities.

1.2.6. Print and turn in *one* data graph with only *one* data run showing. Indicate on the graph what you used to determine the velocity before and after the collision.

v	v'	ω	ω'	L	L'	$\Delta L/L$

2. Yo-yo
   2.1. Setup
      2.1.1. The air table should be preset to have a slight incline. If it is not, have an instructor reset it.
      2.1.2. Turn on the air table's blowers.

   2.2. Experiment
      2.2.1. Let a large disk slide from rest down the table and measure the time of the slide with a stopwatch.
      2.2.2. Now untape the end of the string from the edge of the disk and let it unwind like a yo-yo as it slides the same distance.
      2.2.3. Measure the time to unwind with a stopwatch.
      2.2.4. Do each measurement two more times.

Slide t_s	Unwind t_u

Conclusions

1. Rotational Collision
   1.1. Complete the table in section 1 above to estimate the relative change in total angular momentum ($\Delta L/L$) during each rotational collision. If you use an *Excel* spreadsheet to facilitate the calculations, print and attach it as an appendix. If you do all your calculations by hand, show an example of each calculation. Include a data table in your report.

   1.2. Do your results seem reasonable? Do you observe any trend in your results for the relative change in angular momentum? If so, does the trend seem plausible? Explain.

   1.3. What is the *average* relative change in angular momentum during the collisions?

1.4. Do your data tend to confirm or refute the law of angular momentum conservation? Why?

1.5. The main platter of the rotational apparatus and the auxiliary platter are not completely identical; the main platter has a spindle on the bottom. How might this affect your results? Consider *both* the mass and the way that mass is distributed about the rotation axis in your answer.

2. Yo-yo
    2.1. Use conservation of energy to derive a theoretical expression for the ratio of the speeds of the sliding disk and the unwinding disk, at a given height. Assume that the rotational inertia of the disk is $I = \frac{1}{2} MR^2$.

2.2. For any situation with constant acceleration, how is the average speed related to the final and initial speeds?

2.3. Given the information you just determined about the average speed in each case, predict the ratio of the sliding time to the unwinding time. Report the formula you derive in your write-up.

2.4. From the averages of your measured times, compute the corresponding experimental ratio of the sliding time to the unwinding time. How does this compare to your predicted time? Was mechanical energy indeed conserved? Why or why not?