Experiment 4: Rotators

Name:

Partner:

Date:

Purpose

Study angular momentum conservation and rotational kinetic energy in a rotational collision — and in a race between a slider and a yo-yo.

Equipment

- rotational apparatus
- smart pulley
- signal interface box
- Macintosh computer
- *Data Studio* 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* under a transformation. Something is homogeneous if it is invariant under *translations* and is isotropic if it is invariant under *rotations*.

Procedure

1. Rotational Collision
   1.1. Setup
      1.1.1. Mass the auxiliary platter.
      1.1.2. Measure the radius of the auxiliary platter.

M	*R*

   1.2. Interface
      1.2.1. Connect the smart pulley sensor attached to the rotational apparatus to the signal interface box via digital channel 1.
      1.2.2. Turn on the interface box.
      1.2.3. Wake the computer, launch *Data Studio*, and choose “Create Experiment”.
      1.2.4. Drag a “smart pulley” to channel 1 (or double click the smart pulley icon).
      1.2.5. Double click the graph icon in Displays window to create Graph window.

   1.3. Experiment
      1.3.1. Spin the main platter of the rotational apparatus. Record and display its velocity in *Data Studio*.
      1.3.2. Examine the resulting graph and note the effects of friction — some angular momentum is being transferred to Earth.
      1.3.3. Hold the auxiliary platter *just* above the main platter. Spin the main platter. After recording a few seconds of data, drop the stationary auxiliary platter on the spinning main platter and record a few more seconds of data.
      1.3.4. Use the *Data Studio* tools to determine the velocity of the platters just before and just after the rotational collision. *Note that the platter’s angular velocity is this linear velocity divided by the platter’s radius.*
      1.3.5. Repeat the experiment three times, with different initial velocities.

v	v'	ω	ω'	L	L'	$\Delta L/L$

2. Yo-yo
   2.1. Setup
      2.1.1. Confirm the tilt of the air table.
      2.1.2. Turn on the air table's blower(s).

   2.2. Experiment
      2.2.1. Let a large disk slide from rest down the table.
      2.2.2. Measure the time of the slide with a stopwatch.
      2.2.3. Wrap string around the edge of the disk.
      2.2.4. Let the disk unwind like a yo-yo as it slides the same distance.
      2.2.5. Measure this time with a stopwatch.
      2.2.6. Repeat each measurement three times.

Slide t_s	Unwind t_u

Conclusions

1. Rotational Collision
   1.1. Complete the table above to estimate the relative change in total angular momentum during each rotational collision. (If you use an *Excel* spreadsheet to facilitate the calculations, print and attach it as an appendix.)
   1.2. What is the *average* relative change in angular momentum during the collisions?

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

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. Assuming (correctly) that the both speeds increase proportionally with time, so that the average speeds are half the final speeds, predict the ratio of the sliding time to the unwinding time.

2.3. From the average of your measured times, compute the corresponding experimental ratio of the sliding time to the unwinding time.

2.4. Compute the relative difference between your theoretical and experimental ratios.