Angular Momentum and Rotational Kinetic Energy

Apparatus: Small rotation set disks & rings (2 disks and 1 ring per rotary group), rotary motion sensor, small rods, small bases, PASCO Science Workshop 750 Interface & Power Supplies

Theory:
This experiment is essentially a rotational version of the inelastic collisions lab. Briefly review that lab.

Recall that angular momentum is represented by the eqt'n

$$L = I\omega$$

where L is the angular momentum of an object, I is the moment of inertia for that object and ω is the angular velocity of that object. In this case, saying that angular momentum is conserved means

$$L_i = L_f \qquad \text{or} \qquad I_i\omega_i = I_f\omega_f$$

where the I_i and I_f are the initial and final moments of inertia and ω_i and ω_f are the initial and final angular velocities.

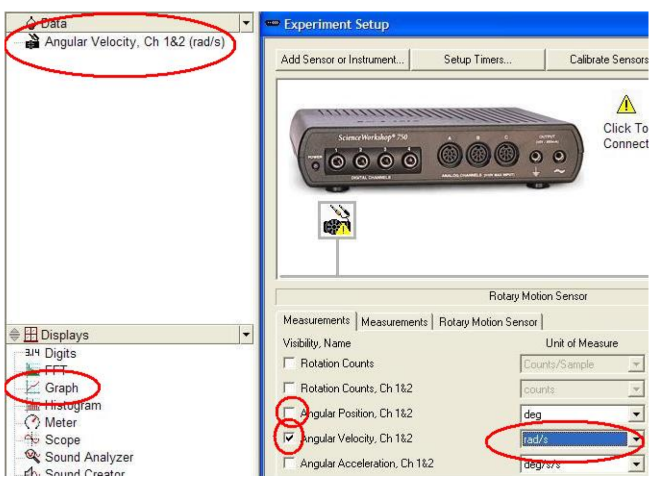
Rotational kinetic energy is defined as

$$RKE = \frac{1}{2}I\omega^2 .$$

PROCEDURE
In this experiment you will change an object's moment of inertia by adding a second object to it. You will determine the initial and final moment of inertia (see the text). In this lab you will use a disk and a thick ring.

Be sure that the disk is screwed on to the rotary motion sensor. Start the disk spinning. Hold the ring a cm or two above the spinning disk. Drop the ring onto the spinning disk. Notice that it is difficult drop the ring such that it lands (and stays) centered above the disk. Practice dropping the ring onto the disk a few times before going further. You might try looking down on the spinning disk from above to see if that helps.

After setting up the experiment you will need to open the Data Studio program on a lab computer. If you have not already done so verify the Pasco interface box is "ON". Verify you have the yellow cable from the Pasco "Rotary Motion Sensor" in digital input 1 on the interface box. The black cable goes into digital input 2.



You can set up the Rotary Motion Sensor to read angular velocity (just like setting up a photogate). You can unclick the Angular Position button and click on the Angular Velocity button. **DONT FORGET TO CHANGE THE UNITS to rad/s!** Then drag the angular velocity (on top left side of figure) down to the graph (bottom left side of figure).

Spin the disk and hit the start button. Verify the computer is taking data. You should see a graph of angular speed versus time being plotted by the computer. It will look a little like the graph below. Think: if your graph is upside down the values are all negative. How could you fix the negative sign? How does the negative sign relate to the spinning? Try using the "xy tool", the 6th button from the left in the graph tool bar (see circled in figure below). When you click this button the dotted lines will appear. You can use these dotted lines to quickly determine the xy coordinates of any point. Simply bring the crosshairs over the point and the xy tool should lock onto the point and read out the coordinates to you. Notice that my graph left out the units…you are expected to figure them out.

On your graph in Data Studio you will notice the angular velocity suddenly drop! Does this agree with conservation of angular momentum? Do you think the energy is conserved? Notice in the graph above that the point selected must be just before the collision. You can quickly get the **experimental angular velocities** of just before the collision (ω_i) and just after (ω_f).

Repeat this experiment once for the ring and two more times with a 2nd disk instead of a ring.

You will need to calculate the moments of inertia of both the annular cylinder and the ring. Measure the mass of the disk and the ring. Measure the radius of the disk as well as the inner AND outer radii of the ring (it is a **thick ring**, not a thin ring). These formulas are available in the text or from the previous lab.

Calculate the initial and final angular momentums and energies using your experimental values of ω_i and ω_f and your calculated moments of inertia. Is L conserved? Is RKE? Should they be?

Experiment 2: Repeat the same procedure as above except this time drop a second disk onto the first disk. Again note the values of ω_i and ω_f and calculate the initial and final angular momentums and energies.

To determine the theoretical change in kinetic energy, do the following:

- Assume that your initial angular speed (ω_i) is known. Also, assume your moments of inertia are known.
- Do a conservation of angular momentum problem to figure out what ω_f *should* be.
- Use this theoretical ω_f to determine what RKE_f *should* be. Answer in terms I_1, I_2, and ω_1. Note: in this case I_1 is the moment of inertia of the first object (the initially spinning disk) and I_2 is the moment of inertia of the second object that is dropped onto the initially spinning disk.
- Using RKE_i (determined from ω_1) figure out what the $\%\Delta RKE$ should be and compare it to theory. You should find that

$$\%\Delta RKE = -\frac{I_2}{I_1 + I_2}$$

Conclusions:

1. Was angular momentum conserved in each experiment?
2. Was rotational kinetic energy conserved in each experiment?
3. Which collision caused the greatest change in angular speed; does it make sense?
4. Are there any trends relating moment of inertia and RKE change? Which collision should cause the greatest change in RKE?
5. What happens to the “lost” RKE?
6. When dropping the disk onto the disk it is very easy to keep the two disks centered. When dropping the ring onto the disk it is almost never centered after the collision. By being off-center, how is the moment of inertia of the disk affected (increased, decreased, not affected)?
7. How should your answer to the previous question affect your values for ω_f?

Will it the collision lose more or less energy when the ring is off-center? Will this tend to make your %differences more positive or more negative? Is that what you found?