CONSERVATION OF ANGULAR MOMENTUM

OBJECT:

- To investigate collisions between rotating bodies, such as disks, rings and plates.

- To verify that angular momentum is conserved during collisions of rotating bodies.

APPARATUS:

1) Computer
2) Pasco *Capstone* Software
3) Pasco 850 Interface
4) Rotary Motion Sensor
5) Rotational Kinematics Apparatus Base
6) Bottom Disk with Bushing
7) Top Disk
8) Steel Ring
9) Steel Rectangular Plate
10) Torpedo Level

INTRODUCTION:

A solid disk is slipped over a (fairly) frictionless rotating vertical spindle. A rotary motion sensor is lightly held against the rim of this disk to measure the disk's angular velocity. This bottom disk is given a spin and then other objects are carefully dropped on top of it. *Capstone* is used to graph the angular velocity of the rotating system before, during, and after the collision takes place. Straight-line fits are used to find the initial angular velocity of the bottom and then the final angular velocity of the total system after the collision.

OBJECT PROPERTIES:

Bottom Disk #1
Mass	$m_{Disk1} = 0.962$ kg
Radius	$r_{Disk1} = 0.127$ m
Moment of Inertia	$I_{Disk1} = 7.758 \times 10^{-3}$ kg m^2

Top Disk #2
Mass	$m_{Disk2} = 0.896$ kg
Radius	$r_{Disk2} = 0.127$ m
Moment of Inertia	$I_{Disk2} = 7.226 \times 10^{-3}$ kg m^2

Ring
Mass	$m_{Disk1} = 0.722$ kg
Radius - Outer	$r_{ORing} = 0.0635$ m
Radius - Inner	$r_{IRing} = 0.0535$ m
Moment of Inertia	$I_{Ring} = 2.471 \times 10^{-3}$ kg m^2

Rectangular Plate

Mass	$m_{Plate} = 0.710$ kg	
Length	$A_{Plate} = 0.226$ m	
Width	$B_{Plate} = 0.051$ m	
Moment of Inertia	$I_{Plate} = 3.176 \times 10^{-3}$ kg m^2	

SETUP:

Insert the rotary motion sensor through one leg of the U-shaped mounting bracket. Slip a rubber band onto the U-shaped mounting bracket so that it rests above the sensor. Drop the other leg of the bracket through the hole in the base and stretch the rubber band over the thumb screw in the middle of the base.
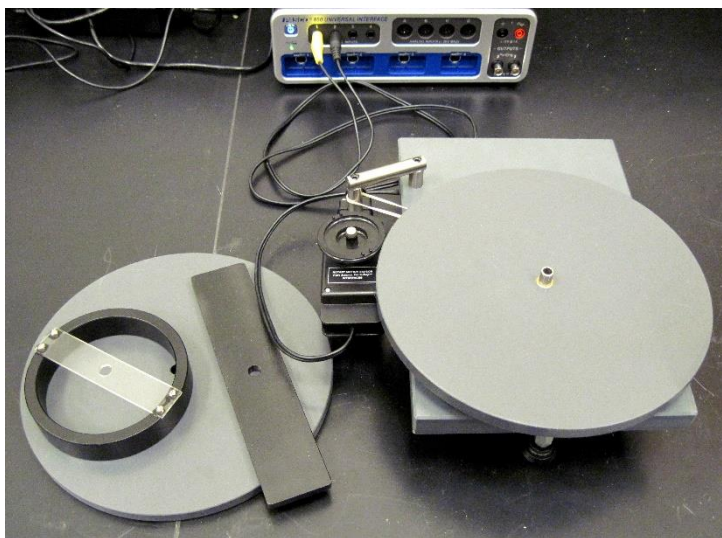

Place the bottom disk carefully over the vertical spindle that is inserted into the ball bearing in the apparatus base. Use the torpedo level to adjust the three base feet until the bottom disk is level in all directions. Tighten the locknuts on the feet so that they won't get out of adjustment as you perform the experiment.

Adjust and tighten the thumbscrew of the rotary motion sensor so that its rubber tire runs smoothly and squarely on the edge of the disk. The rubber band should provide a slight amount of pressure to keep the motions sensor's rubber tire in contact with edge of the disk.

Insert the yellow-marked plug in the DIGITAL CHANNELS 1 jack and black plug in the DIGITAL CHANNELS 2 jack.

Browse to the Conservation of Angular Momentum template and double-click:
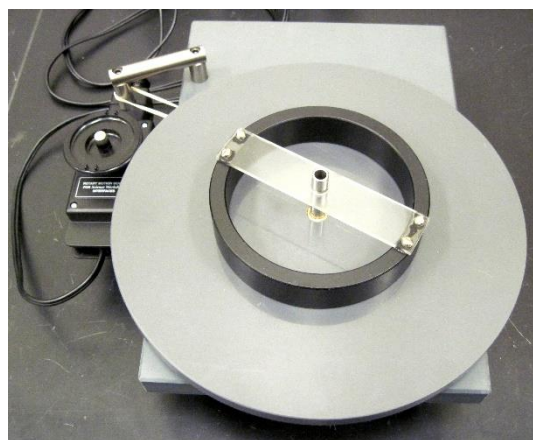
K:\Physics\Demonstrations\Conservation of Angular Momentum

DEMONSTRATION:

For the example of a collision between the bottom disk #1 and the ring:

1. Click on <Record>
2. Give the disk a clockwise spin
3. Drop the ring on the center spindle
4. Click on <Stop>

If you look at the sample data graph, you can see that there are five sections: (1) the bottom disk is motionless, (2) the disk is given its initial angular velocity that, because the ball bearing support is not really frictionless, starts to decrease immediately, (3) the collision occurs but the two objects are spinning at different rates, (4) the objects have locked together and are rotating with the same angular velocity, and finally (5) the rotation stops.
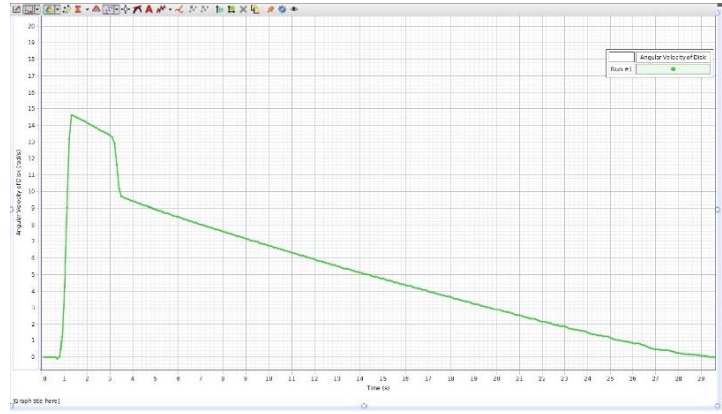
ANALYSIS:

Because the overall system is slowing down due to bearing friction during the time that the collision is occurring, we cannot directly read off of the graph the initial and final angular velocities and get the best results. Instead, we will extrapolate the initial and final data through the period of the collision and use these values found at the mid-point of the collision period as our initial and final angular velocities. This procedure will minimize the effect that friction during the collision has on the analysis.

1. Use the Hand and the Scale double-headed arrow to shift and scale the graph to magnify the region of interest.
2. Click on the Highlight Range Tool and draw a box around the initial angular velocity portion of the graph.
3. Click on the Curve Fitting Tool down arrow and select "Linear".
4. Click on the Curve Fitting tool button to draw the best straight line through the selected data.

5. Again, click on the Curve Fitting Tool and draw a box around the final angular velocity portion of the graph.
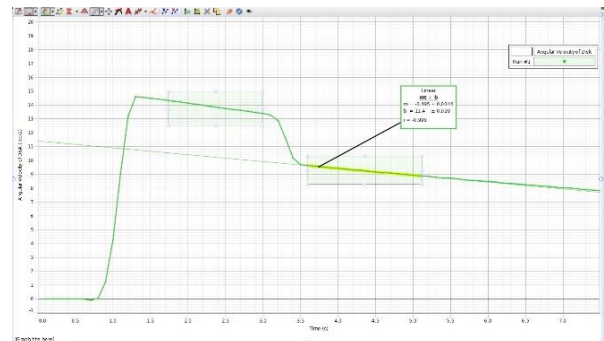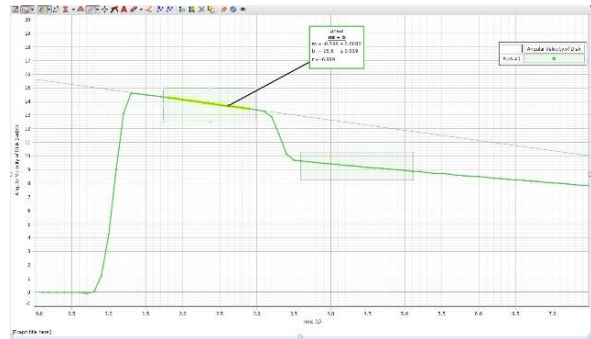
6. Find the mid-point of the collision time t_{coll} and read the angular velocities ω_i and ω_f from the Angular Velocity scale for this time – the line intersections.

   [*Note that in the graph below, extra lines have been added for illustration*].
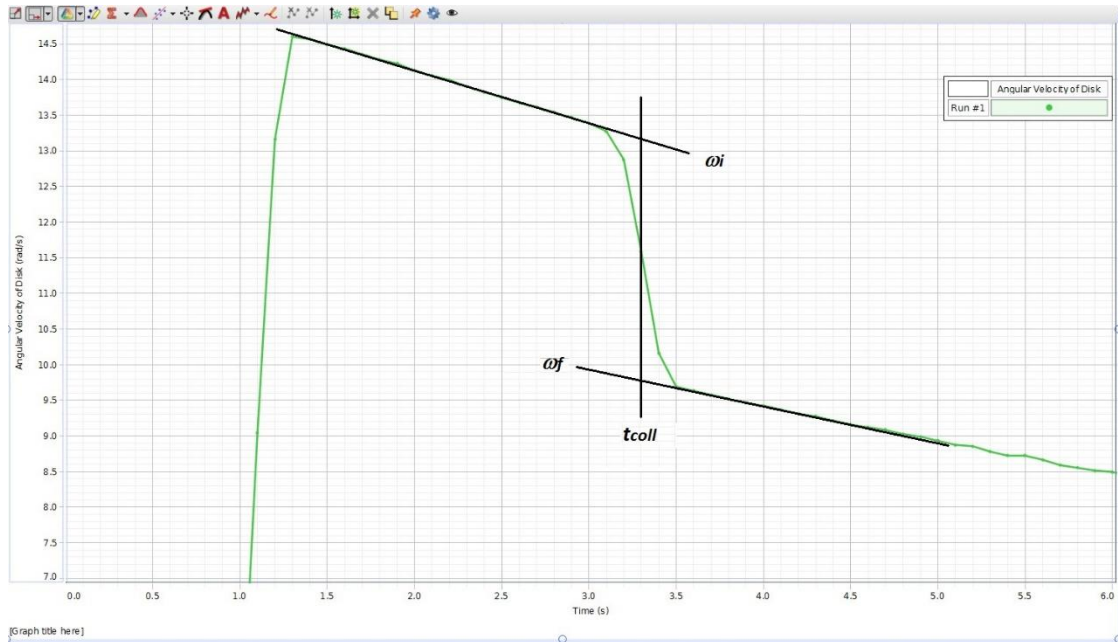
CALCULATIONS:

In the above graph:

   t_{coll} = 3.3 s
   ω_i = 13.2 rad/s
   ω_f = 9.8 rad/s

Angular Momentum L

   $L_i = I_{Disk1} \times \omega_i$

   $L_f = (I_{Disk1} + I_{Ring}) \times \omega_f$

Again, in our Disk-Ring example:

   $L_i = 7.758 \times 10^{-3} \times 13.2 = \underline{0.102 \text{ kg m}^2/\text{s}}$

   $L_f = (7.758 \times 10^{-3} + 2.471 \times 10^{-3}) \times 9.8 = \underline{0.100 \text{ kg m}^2/\text{s}}$