SAN DIEGO MESA COLLEGE Name:______________________________

PHYSICS 195 LAB REPORT Date:__________________Time:________

TITLE: Angular Momentum Partners:______________________________

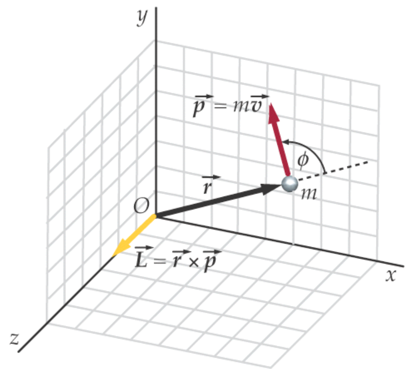
____

____

____

Objective:

To investigate rotational collisions both for conservation of angular momentum and non-conservation of mechanical energy.



Theory:

Basic definition of angular momentum about the origin for a particle of mass m:

$$\vec{L} = \vec{r} \, x \, \vec{p}, \quad \left|\vec{L}\right| = rp\sin\phi$$

Angular momentum of a rigid body about a fixed axis:

$$\vec{L} = \mathrm{I} \, \vec{\omega}$$

Angular momentum defined in analogy to Newton's Second Law:

$$\sum_{ext} \vec{F} = \frac{d\vec{P}}{dt} \rightarrow \sum_{ext} \vec{\tau} = \frac{d\vec{L}}{dt}$$

Conservation of angular momentum:

$$\text{if } \sum_{ext} \vec{\tau} = 0 \text{ , then } \frac{d\vec{L}}{dt} = 0 \quad \text{thus } \vec{L}_o = \vec{L}_f$$

Equipment:

Rotating air table
Steel discs
Optical reader
Meter stick
Ramp
Air regulator
Drop pin
Electronic balance
Tube clamp
Ball catcher

Procedure: Part I: Inelastic collisions between rotating objects

For this portion of the lab you will be using both steel discs.

1. The rotational inertia of each steel disk is calculated from the physical measurements of their inner and outer diameters, and masses. **Take care to not scratch the disk surfaces!**
2. The apparatus is set up, <u>cleaned and leveled</u> in the same manner as the previous experiment. <u>The bottom air hose must be clamped</u>. Air pressure set to 8 – 10psi. The two steel disks are used with the "drop pin" (long black-capped pin), so that each disk rotates smoothly and independently.
3. The first type of collision is accomplished by holding the bottom disk stationary and spinning the top disk (300-400 bars/s). **Note: do not exceed 400 bars/s in today's lab**. Record the reading for the top disk and immediately pull the pin. Wait for two seconds then record the reading for the common velocity of the two disks after the collision. Repeat this process for a total of three collisions. Record each collision in your data table.

Note the two-second delay in recording the final reading, due to the nature of the optical reader. This is true throughout the lab. Do not wait longer, as friction will enter as an external torque.

4. The second type of collision, is accomplished by spinning the bottom disk in one direction and the top disk in the opposite direction, before the collision. One of the velocities should be **much** greater than the other in order to get a significant final velocity after the collision. Choose 300-400 bars/s for one disk, and 100-200 bars/s for the other. Again, some preliminary trials will assure **best** data.
5. The display switch must be flipped to measure both the reading for the top disk and the bottom disk before removing the drop pin. Each time you flip the switch or pull the drop pin, be sure to wait a full two seconds before recording the new display reading. Be sure to record the direction of the rotation [CW(-) or CCW(+)] for each disk. Repeat this process for a total of three collisions. Record each collision in your data table.
6. The appropriate angular velocities for two collisions are measured with the optical reader in bars/s; and converted to radians/s by the "reader-factor," 0.0314 rad/bar.

Data: Part I: Inelastic Collisions – Type 1

Inner diameters: Inner radii:

	Mass kg	D_i m	D_o m	r_i m	r_o m	I kgm^2
top disk						
bottom disk						

Show a sample calculation, with units, for I: Hollow cylinder: $I_{cm} = \frac{M}{2}(R_{outer}^2 + R_{inner}^2)$

Trial #1				Trial#2				Trial#3			
READING (bars/s)		Angular velocity ω (rad/s)		READING (bars/s)		Angular velocity ω (rad/s)		READING (bars/s)		Angular velocity ω (rad/s)	
R_{iT}		ω_{iT}		R_{iT}		ω_{iT}		R_{iT}		ω_{iT}	
R_{iB}	0	ω_{iB}	0	R_{iB}	0	ω_{iB}	0	R_{iB}	0	ω_{iB}	0
R_f		ω_f		R_f		ω_f		R_f		ω_f	

Show a sample calculation with units

Data: Part II: Inelastic Collisions – Type 2

Trial #1				Trial#2				Trial#3			
READING (bars/s)		Angular velocity ω (rad/s)		READING (bars/s)		Angular velocity ω (rad/s)		READING (bars/s)		Angular velocity ω (rad/s)	
R_{iT}		ω_{iT}		R_{iT}		ω_{iT}		R_{iT}		ω_{iT}	
R_{iB}		ω_{iB}		R_{iB}		ω_{iB}		R_{iB}		ω_{iB}	
R_f		ω_f		R_f		ω_f		R_f		ω_f	

Show a sample calculation with units

Analysis: Part I:

ANALYSIS: Test for conservation of angular momentum in these inelastic collisions:

	L_{iT}	L_{iB}	$L_{i\,(T+B)}$	$L_{f\,(T+B)}$	% difference	L conserved?
Type 1	$I_T\omega_{i\,T}$ (kg m^2/s)	$I_B\omega_{i\,B}$ (kg m^2/s)	$I_T\omega_{i\,T} + I_B\omega_{i\,B}$ (kg m^2/s)	$(I_T + I_B)\,\omega_f$ (kg m^2/s)		
Trial 1						
Trial 2						
Trial 3						

Type 2	$I_T\omega_{i\,T}$ (kg m^2/s)	$I_B\omega_{i\,B}$ (kg m^2/s)	$I_T\omega_{i\,T} + I_B\omega_{i\,B}$ (kg m^2/s)	$(I_T + I_B)\,\omega_f$ (kg m^2/s)	% difference	L conserved?
Trial 1						
Trial 2						
Trial 3						

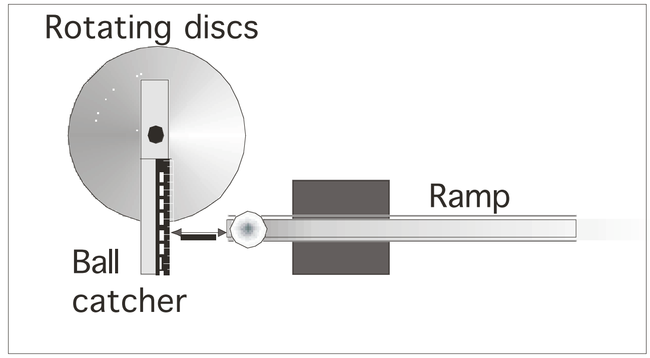
Show a sample calculation with units for each quantity.

Analysis: Part I, continued: Test for conservation of kinetic energy in the inelastic collisions:

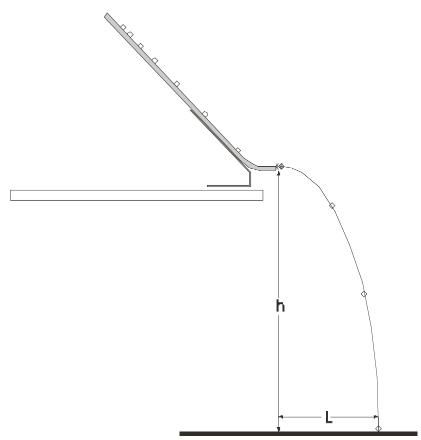
	$K_{(rot)iT}$ (Joules)	$K_{(rot)iB}$ (Joules)	$K_{(rot)I}$ (Joules)	$K_{(rot)f}$ (Joules)	% difference	Kinetic Energy conserved?
Type 1	$\frac{I_T\,\omega_{iT}^2}{2}$	$\frac{I_B\,\omega_{iB}^2}{2}$	$K_{rot\ iT} + K_{rot\ iB}$	$\frac{(I_T + I_B)\,\omega_f^2}{2}$		
Trial 1						
Trial 2						
Trial 3						
Type 2						
Trial 1						
Trial 2						
Trial 3						

Show a sample calculation with units for each quantity.

Part II: Equivalence of linear and angular momentum
In this portion of the experiment a steel ball rolls down a ramp and is caught by the 'ball catcher' that is mounted on a freely rotating steel disc.



1. **Determination of $I_{ball\ +\ catcher\ +\ disk}$:** Remove the hanging mass. Attach the string to the pulley. Mount the ball catcher on top of the small torque pulley on top of the steel disk, using a gray thumbscrew. <u>The bottom hose must be unclamped to keep the bottom disk stationary.</u>
2. **Make sure that the ball is centered at the 8 cm mark**.
3. Use the method of the previous experiment (by letting the hanging mass fall toward the ground) to determine the rotational inertia of the ball, the catcher, and the disk: ($I_{ball\ +\ catcher\ +\ disk}$). Record this in your data table in section **1** of Part II for three trials.
4. **The collision:** <u>The bottom hose must be unclamped to keep the bottom disk stationary.</u> Position the ramp on the air-table as shown in the diagram. Release the ball from a marked starting point so that it is caught by the ball-catcher exactly 8.0 cm from the axis of the disk. (The end of the ramp should be perpendicular to and about 0.2 cm from the ball catcher.) Remove the ramp from the table as soon as the ball is caught and record the **highest final** reading soon after the collision. Perform two trial runs, and record the average of the highest two readings resulting from these multiple measurements.
5. **Determination of v_{oBall} :** Position the ramp at the edge of the lab table as shown in the diagram below. Use the same starting position for the ball near the top of the ramp as in step 4, and <u>record the measurements on the diagram</u> necessary to determine the speed of the ball as it leaves the ramp. Record this data in section **3** of Part II.



Data: Part II: Equivalence of Linear and Angular Momentum

1. Rotational inertia of ball, catcher, and disk, $\mathbf{I_{ball + catcher + disk}}$ **:**

Trial #1

bars/s																
Δ bars/s																
average Δ bars/s =																

Trial #2

bars/s																
Δ bars/s																
average Δ bars/s =																

Trial #3

bars/s																
Δ bars/s																
average Δ bars/s =																

Overall average Δ bars/s =

$$\alpha_{ave} = \frac{\Delta\omega}{\Delta t} = \frac{\left[\left(\frac{\Delta \text{ bars}}{\text{s}}\right)\left(\frac{.0314 \text{ rad}}{\text{bar}}\right)\right]}{2 \text{ seconds}} = \underline{\hspace{8cm}}$$

Radius of small torque pulley = ______________________________

Hanging mass providing torque = _________________ kilograms

$\tau = mgr - mr^2\alpha =$ ______________________________

1. $I_{ball + catcher + disk} = (\tau / \alpha) =$ ________________________________

2. Let L_b be the angular momentum of the ball about the system's axis of rotation, JUST BEFORE THE COLLISION with the ball catcher. Thus L_b is the initial angular momentum of the system before the collision: $L_i = L_b$

Mass of the ball: ________________ kilograms

Range of ball: x = ____________________ meters

Linear speed of the ball before collision may be expresses as $\mathbf{v_{oBall}} = x / t = x / \sqrt{2y/g}$. Derive this expression in the space provided. Be explicit in use of vector notation:

3. $\mathbf{v_{oBall}} =$ ________________**m/s**

$\left|\vec{L}_{ball}\right| = \left|\vec{L}_i\right| = \left|\vec{R} \times \vec{P}\right| = mvR$. Draw a top-view diagram of the pre-collision system. Clearly indicate the distance R, and calculate the initial angular momentum of the ball about the axis of rotation.

$L_{ball} = L_i =$ ____________________

Angular momentum of the ball, catcher and disk, $L_{f(system)}$ about the axis of rotation immediately <u>AFTER THE COLLISION.</u>

The average of the highest two readings R_f for the post-collision system $R_{f(average)}$ (bar/s)	ω_f (rad/s)	$I_{f(system)} = I_{ball + catcher + disk}$ (kgm^2)	$L_{f(system)}$ (kgm^2/s)

Show a sample calculation with units for each quantity:

3. Test for Conservation of Angular Momentum:

Collision	$L_i = L_{ball}$ (kg m^2/s)	$L_f = I_f\omega_f$ (kg m^2/s)	% difference	Is L conserved?

Show a sample calculation with units for each quantity:

4. Test for Conservation of Kinetic Energy:

Collision	$K_{i\ ball} = K_{trans} + K_{rot}$ (Joules)	$K_{f(system)} = \frac{I_{f(sys)}\ \omega_f^2}{2}$ (Joules)	% difference	Is K conserved?

Show a sample calculation with units for each quantity:

Conclusion and Summary of Results:

Write a brief conclusion, including a brief discussion of the physics involved in this experiment, including possible sources of error, and indicate whether your results give support or validate the purpose of the lab exercise.