

Name: \_\_\_\_\_

Partner(s): \_\_\_\_\_

Date: \_\_\_\_\_

## Angular Momentum

### 1. Purpose:

In this lab, you will use the principle of conservation of angular momentum to measure the moment of inertia of various objects. Additionally, you develop a qualitative “feeling” for moment of inertia.

### 2. Theory:

For a system in the absence of any net *external* torque, the angular momentum,  $L$ , is conserved (*i.e.* remains constant). This is the principle of conservation of angular momentum. In the case of two rotating bodies that undergo collision, conservation of angular momentum says:

$$\begin{aligned} L_{\text{before}} &= L_{\text{after}} \\ (I_1\omega_1 + I_2\omega_2)_{\text{before}} &= (I_1\omega_1 + I_2\omega_2)_{\text{after}} \end{aligned} \quad (1)$$

### 3. Procedure:

In this experiment, you will examine a collision between an object having a known moment of inertia, a solid disk, and an object with an unknown moment of inertia. From this, you will determine the moment of inertia of the unknown object using the principle of conservation of angular momentum.

- To do this, you will set a turntable (the disk) into rotation with an angular velocity  $\omega_0$ , and hold the unknown object just above it. If we call the turntable “object #1”, and the unknown “object #2”, the angular momentum before the collision is:

$$L_{\text{before}} = I_1\omega_0 \quad (2)$$

- If the unknown object is suddenly dropped onto the rotating turntable so that the two objects rotate with a common angular velocity  $\omega_f$  then:

$$L_{\text{after}} = (I_1 + I_2)\omega_f \quad (3)$$

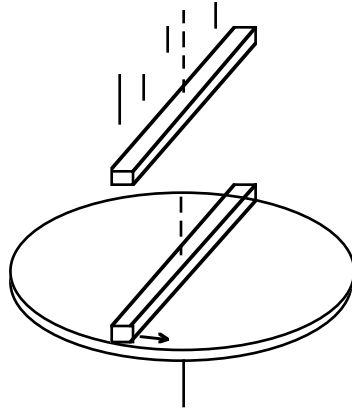


Figure 1: Depicting a rotational collision

Applying the principle of conservation of angular momentum to this scenario yields Equation (4).

$$I_1\omega_0 = (I_1 + I_2)\omega_f \quad (4)$$

This can be solved for the unknown's moment of inertia *about the axis of rotation*:

$$I_2 = I_1 \frac{\omega_1 - \omega_2}{\omega_2} \quad (5)$$

- You can find the moment of inertia of the turntable from static measurements and the formula from your text for the moment of inertial for a disk.
- Then, by measuring the initial and final angular velocities of the rotating objects, you'll be able to find a value for the moment of inertia of the unknown object.

This method can be used to determine the moment of inertia for any object and is, consequently, very useful when the geometry of the object would make a theoretical calculation difficult. In this experiment, however, you will use three simple objects as unknowns: a slab, hollow cylinder and a dumbbell. In this way you can compare your experimental results with theory. However, *don't* look up the moments of inertia of these objects in your textbook just yet. You'll make *estimates* in the lab.

- Before you start (and before you consult your textbook), try to *estimate* a value for the moments of inertia for the objects used in this lab.

Object	Estimate ( kg·m <sup>2</sup> )
Slab	
Dumbbell	
Hollow Cylinder	

Later, when you compare your initial estimate to your measurement, it should help you to retain some sense of numerical magnitude for moments of inertia.

- As described above, you will set a turntable into rotation with an angular velocity  $\omega_0$ , and hold the object with an unknown moment of inertia above the turntable. Once the rotational speed of the turntable has been measured at least twice, you will drop the object.
- In order to compare your moment of inertia results to those presented in your textbook, you need to drop the unknown object onto the very *center* of the turntable. If it is dropped *off-center*, the moment of inertia you measure is still the moment about the axis of rotation - but is *not* the moment about any axis of symmetry of the unknown object itself, which is what is presented in your text. Your results will depend upon how well you align and drop the objects so that they are centered over the axis of rotation. It's up to you to find a good technique for doing this. [Does height perspective help or hurt?] Ask for any equipment you might need (plumb bobs, levels, *etc.*). A page of circular graph paper might be useful (perhaps you'd cut a hole in it?). You might wish to have each person in the group try dropping the objects five times without making any measurements, just to see who's best at dropping the objects into alignment.

Note: The dropped object and the turntable must be at rest with respect to each other; otherwise the value that you measure for  $\omega_2$  is not the same as in Equation (3).

- To measure the angular velocity, we will again use the Data Studio™ software and a photogate using the “Photogate” sensor.
- Attach a paper flag to the turntable. The photogate can measure the time it takes the paper wedge to pass through a photogate and from this, you can calculate the average angular velocity,  $\omega = \Delta\theta / \Delta t$ , of the disk during its passage through the photogate.
- ❖ With this in mind, what factors influenced your choice for the size of the paper wedge that you will be using in this experiment?

- ❖ The flag passes through the photogate a distance  $r$  from the axis of rotation. The width of the flag at this point is  $w$ . In the space below, use trigonometry to find the angle,  $\Delta\theta$ , subtended by the flag at the point it passes through the photogate:

- Your data can be recorded below.

Turntable	
$M_{d1} =$	_____ k
$R_{d1} =$	_____ m
$M_{d2} =$	_____ k
$R_{d2} =$	_____ m
$I_{d1} =$	_____ kg m <sup>2</sup>
$I_{d2} =$	_____ kg m <sup>2</sup>
$I_{\text{turntable}} = I_{d1} + I_{d2} =$	_____ kg m <sup>2</sup>

Slab	
M = _____	kg
a = _____	m
b = _____	m
$\omega_1$ = _____	rad/s
$\omega_2$ = _____	rad/s

Hollow Cylinder	
M = _____	kg
$R_1$ = _____	m
$R_2$ = _____	m
$\omega_1$ = _____	rad/s
$\omega_2$ = _____	rad/s

Dumbbell	
M = _____	kg
r = _____	m
$\omega_1$ = _____	rad/s
$\omega_2$ = _____	rad/s

	Slab	Dumbbell	Hollow Cylinder
Experimental ( $\text{kg}\cdot\text{m}^2$ )			
Theoretical ( $\text{kg}\cdot\text{m}^2$ )			
% Error			



**5. Initiative:**

**6. Conclusions:**