Name ____________________ Section ____________ Date ____________

CONCEPTUAL PHYSICS	Activity

Rotational Motion: Conservation of Angular Momentum **Take Physics for a Spin**

Sit on it and Rotate

Purpose
To experience conservation of angular momentum by feeling its effects

Apparatus
low-friction rotating stool
1 bicycle wheel with handles
2 dumbbells (or equivalent, such as bricks)
an assistant (instructor or lab partner, for example)

SAFETY CAUTION: BE CAREFUL AROUND THE SPINNING BICYCLE WHEEL. KEEP FINGERS AND DANGLING OBJECTS (LONG HAIR, JEWELRY, LOOSE CLOTHING, ETC.) AWAY FROM THE SPOKES.

Discussion
In the absence of external torques, the angular momentum of a system is conserved. In this activity, you will feel what that statement means. You will also learn some implications of that principle.

Procedure
PART A: THE ICE CAPS MELTETH

1. If the polar ice caps were to melt, a considerable mass of water would flow from the poles toward the equator. Would this tend to make days longer or shorter? Explain.

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Step 1: Sit on the rotating stool so that you are balanced and comfortable. Obtain the dumbbells; hold one in each hand. Raise the dumbbells over your head and lift your feet off the ground.

Step 2: Let your assistant apply a gentle torque to get you rotating no faster than one revolution per second.

Figure 1.a. Ice Cap Frozen; Dumbbells over Head

Figure 1.b. Ice Cap Melting

Figure 1.c. Water Fully Redistributed

Figure 1.d. Ice Cap Freezing Back Up for Repeat

Step 3: Let the ice caps melt: While keeping your arms fully outstretched, move the dumbbells from over your head to straight out (see Figure 1). Bring the dumbbells back up and repeat so you have a clear sense of the changes you feel, if any, as your arms move.

a. What happens to your angular speed (rate of rotation) as you move the dumbbells from the "poles" to the "equator"?

b. How would the length of the day be affected if the polar ice caps were to melt?

PART B: SLICK SPOT

Suppose you're riding a bicycle and you suddenly find yourself on a slick spot, such as a patch of ice or an oil slick on the roadway. Should you keep pedaling or lock the wheels as you slide across the slick spot? To find out, complete the following activity.

Step 1: Hold the non-rotating bicycle wheel by its handles. Orient the bicycle wheel vertically (as it would be if you were riding the bicycle).

Step 2: Quickly twist the wheel into a horizontal orientation (as it would be if you were to fall). See Figure 2.

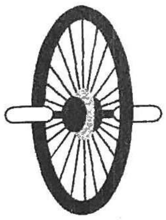

Figure 2a. The Bicycle Wheel, Vertical

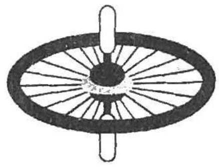

Figure 2b. The Bicycle Wheel, Horizontal

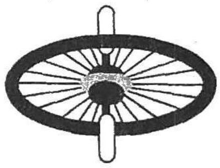

Figure 2c. Horizontal with the other Handle Up

Step 3: Rotate the bicycle all the way over (180°) so that it is horizontal with the other handle up.

Step 4: Reorient the wheel vertically. Have your assistant give the wheel a significant torque so that the wheel spins rapidly in the vertical orientation.

Step 5: Now repeat steps 2 and 3: twist the rotating wheel to one horizontal orientation and then back over to horizontal with the other handle up.

Step 6: It's safe to slow the wheel by gently pressing the palm of your hand to the rubber tread of the wheel. Stopping the wheel on the floor often leaves a mark.

Step 7: Allow your assistant to slowly bring the wheel to a stop by applying ***gentle*** pressure to the outer surface of the tire with the palm of his or her hand.

a. When is it harder to "wipe out" (fall): when the wheel is at rest or when the wheel is spinning?

b. What's the best strategy for remaining upright when you hit a slick spot on the road?

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PART C: THE GO SPIN ZONE

Conservation of angular momentum has curious consequences when you use the bicycle wheel and the rotational stool together.

Figure 3

Step 1: Sit on the rotational stool so that you are balanced and comfortable.

Step 2: Have your assistant give you the bicycle wheel. Hold it vertically. See Figure 3.

Step 3: Keep your body stationary (keep your feet on the ground, if possible), keep your arms rigid, and hold the bicycle wheel tightly while your assistant applies a significant torque to the wheel to get it spinning.

Note: If viewed from overhead, there would be no angular momentum in the system (you on the rotational stool holding the bicycle wheel). No spin could yet be observed. See Figure 4.

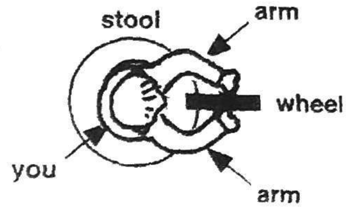

Figure 4. As Seen from Overhead

Step 4: Without pushing off, carefully free your body by lifting your feet. You should not be rotating at this point.

Step 5: Turn the spinning bicycle wheel from a vertical orientation to a horizontal orientation.

What happens when you turn the bicycle wheel on its side?

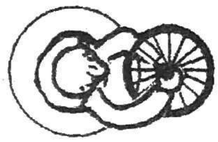

Figure 5. As Seen from Overhead.

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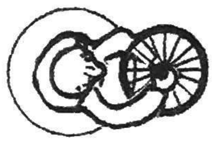
Step 6: Turn the bicycle wheel all the way over so that it is horizontal with the other handle up.

a. If seen from overhead, are you spinning clockwise or counterclockwise? Answer below and add an arrow showing your spin to Figure 5.



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b. If seen from overhead, is the bicycle wheel spinning clockwise or counterclockwise? Answer below and add an arrow showing the wheel's spin to Figure 5.

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c. Which object spins with greater angular ***speed:*** you or the bicycle wheel?

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d. Which object has more rotational ***inertia:*** you or the bicycle wheel?

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e. If seen from overhead, which object has more ***angular momentum:*** you or the bicycle wheel?

f. Before the bicycle wheel was turned on its side, there was a total of ***zero*** angular momentum in the system. What is the total angular momentum in the system when the bicycle wheel is turned on its side? Explain.

Summing Up

1. The Mississippi River flows from north to south along the surface of the Earth. It picks up solid material and deposits it in the delta, where the river meets the Gulf of Mexico. What is the effect of this deposition on the rate of rotation of the Earth? And what effect does this have on the length of the day?

2. River reservoirs hold back substantial masses of water that would otherwise flow toward the equator. What is the effect of this retention on the rate of rotation of the Earth? And what effect does this have on the length of the day?

3. Suppose you are spinning on the rotating stool with arms outstretched and dumbbells in your hands. And suppose you pull the dumbbells in toward your chest.
   a. What happens to your angular speed as you pull the dumbbells in?

   b. What happens to your rotational inertia as you pull the dumbbells in?

   c. What happens to your angular momentum as you pull the dumbbells in?