PhyzLab: Sit on It and Rotate!

an investigation of angular momentum

PERIOD	1.		
	2.		
GROUP	3.		
	4.		

• Purpose •

In this investigation, you will experience various aspects of angular dynamics. You will use your experiences, along with your knowledge of angular dynamics, to answer a few *gedanken* questions.

• Apparatus •

___ dumbbells (or equivalent)
___ low-friction rotating stool
___ bicycle wheel with handles
___ instructor (or equivalent)

• Procedure •

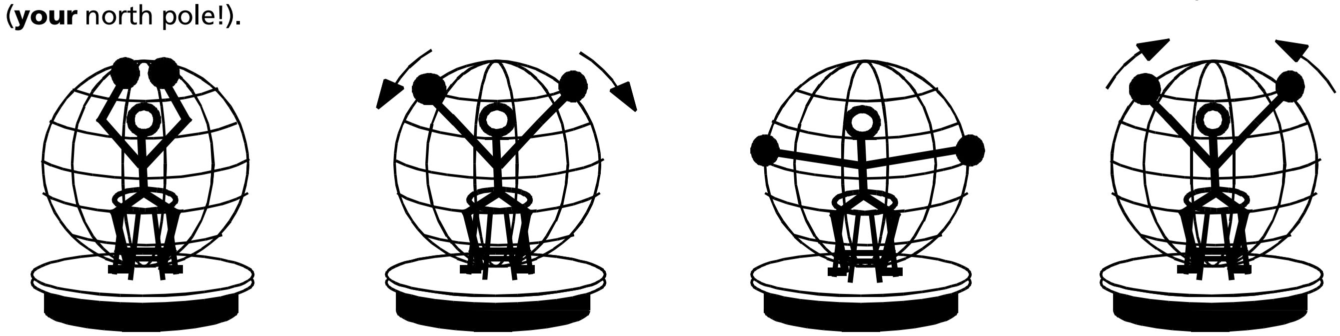
1. THE ICE CAP MELTETH
Station: The rotating stool and the dumbbells

Read the following questions, but don't answer them until you've performed "The Ice Cap Melteth" procedure.
a. Question. If the polar ice caps were to melt, would days be longer, shorter, or unaffected? Explain.

b. Question. The Mississippi River carries a sizable quantity of earth south to the Gulf of Mexico. Does this have an effect on the earth's rotation? (Consider whether or not the mass gets nearer or farther from the earth's axis of rotation as it moves southward.) Explain.

c. Procedure. Sit on the stool of the rotating platform. Make sure your upper body is straight and above the center of the turntable. **You are now the earth!** (Don't you feel important! Remember, your mass is now 6×10^{24} kg! Wow!)

d. Let the 5-lb. or 10-lb. dumbbells represent the mass of the north pole ice cap. Hold them over your head (**your** north pole!).



You as "The Earth" with polar ice cap intact.
Ice cap begins to melt; "water" flows south.
"Water" migrates toward the equator.
ice cap refreezes; "water" freezes north.

e. The instructor will now apply a torque so that you begin to rotate.

f. As you rotate, allow the ice cap to "melt" by lowering the dumbbells while keeping your arms locked **fully extended!** (Remember, if the ice cap melts, the water won't fall into the center of the earth! It will redistribute toward the equator!) For comparison, also "refreeze" the ice cap north again. Repeat.

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g. Describe the result:

Now go back to questions a and b and answer them.

h. Analysis: Angular Momentum. Consider what happens to you if—while rotating—you move the dumbbells out as far as you can and then move them back in toward your chest (see diagram at the bottom of this page).

i. Does your mass change during this procedure? Explain.

ii. Does your rotational inertia change during this procedure? Explain.

iii. Does your angular speed change during this procedure? Explain.

iv. Angular momentum is the product of rotational inertia and angular speed ($L = I\omega$). Does your angular momentum change during this procedure? Explain.

i. Analysis: Kinetic Energy. Suppose you were spinning rapidly with the weights held halfway out.

i. The weights would naturally tend to move

___outward (away from you). ___inward (toward you).

ii. What kind of work—if any—would be required to move the weights inward toward you?

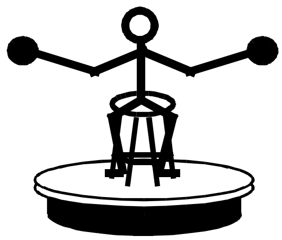
___Positive. ___Negative. ___Zero.

Defend your answer.

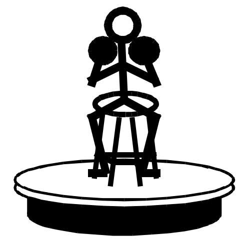
iii. Angular momentum is the simple product of I and ω (and thus depends equally on the value of each). Rotational kinetic energy, however, depends more on ω than it does on I ($KE = {}^1/_2 I\omega^2$). Consider your findings in questions h.ii., h.iii, and h.iv above; what happens to your rotational kinetic energy when you pull the weights inward? (For example, suppose I goes from 6 kg·m^2 to 2 kg·m^2 while ω goes from 3 rad/s to 9 rad/s. What would happen to angular momentum and what would happen to kinetic energy?)

iv. What connection—if any—is there between the answers of questions ii and iii?

j. On the diagrams below, draw the letters of the variables (*I*, ω, *L*, *KE*) proportionally to the size of the variable. Note that I've already indicated that the rotational inertia is greater in one configuration than it is in the other.



I	I
ω	
L	
KE	



I	I
ω	
L	
KE	

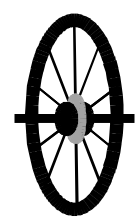
2. THE DISEMBODIED BIKE WHEEL
Station: The bicycle wheel.

Consider the following question and answer only after performing the "Disembodied Bike Wheel" procedure.

a. Question. Suppose you're riding along on your bike one day when suddenly, you're transported through time and space to an icy MICHIGAN winter day. Unfortunately for you, you're still riding your bike. As you're riding, you hit a patch of ice. If you don't wish to fall over before getting back on a rough surface, you should (circle one)
A. allow the wheels to keep spinning.
B. apply the brakes to stop the wheels.

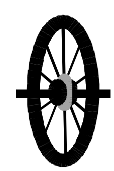
PLEASE NOTE: USE CAUTION WHEN HANDLING OR ASSISTING WITH THE BIKE WHEEL. HOLD THE SPINNING WHEEL WITH TWO HANDS: ONE ON EACH SIDE. BE CAREFUL OF THE SPOKES. STOP THE WHEEL BY GRADUALLY PRESSING YOUR PALM AGAINST THE RUBBER WHEEL OR BY SKIDDING IT AGAINST THE OFFICIAL SKID BOARD.

DO NOT ALLOW THE WHEEL TO SKID ON THE FLOOR!!!

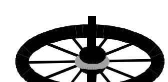


b. Procedure. Hold the wheel by the axle on both sides (use both hands) and hold the wheel vertically. With the wheel NOT spinning, try to rotate the axle 90° so that the wheel is horizontal. This procedure indicates the wheel's resistance to a "wipe-out" when the wheel is stopped.

c. Procedure. Try again, starting with a vertical orientation, and "wiping-out" to the horizontal orientation, only this time, have your partner give the wheel a large angular speed. Explain the result, and compare a spinning wheel to non-spinning wheel.



Vertical



Horizontal

Answer the question at the top of the page knowing what you know now.

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d. But why? Why did the wheel act that way?
Remember linear momentum? It was a vector. A hockey puck moving across the ice has momentum. Its momentum could be changed by changing its speed OR by changing its direction. Both changes in momentum (magnitude or direction) require impulse.

Now consider the spinning wheel. The spinning wheel has an angular momentum. Its angular momentum is specified by its rotational inertia and its angular velocity; since angular velocity is a vector, the direction or plane of spin is as important as the speed of rotation. To change the directional orientation of the spinning wheel requires an angular impulse: a torque acting over an interval of time.

Angular momentum stabilizes you as you ride a bicycle!

i. Why is it so difficult to ride a bike at low speeds?

ii. What is one advantage of imparting a spin to a football when throwing it?

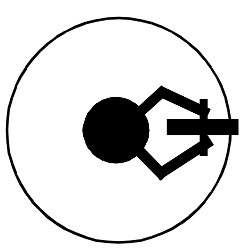
3. WARP 3 DRIVE
Station: The rotating stool and the bicycle wheel

a. Sit on the rotation stool and have someone give you the bicycle wheel. Hold the wheel vertically, and have someone give it a large torque (giving it a high angular speed).
b. Now tilt the wheel over by 90°. What happened?

c. Tilt the wheel back to its original vertical orientation. What happened?

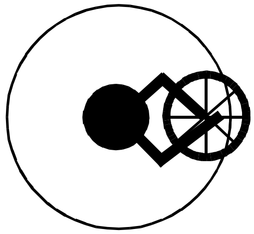
NOTE: cw = clockwise; ccw = counter-clockwise

TOP VIEW



d. Viewing from the top, what is the direction of the initial angular momentum of the system?

Total angular momentum **L** is now **cw** **ccw** **0.**

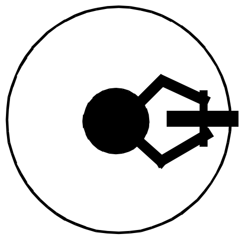


e. Draw arrows to indicate ω_{WHEEL} and ω_{YOU}.

The direction of ω_{WHEEL} is: **cw** **ccw**

The direction of ω_{YOU} is: **cw** **ccw**

Total angular momentum **L** is now **cw** **ccw** **0.**



f. The wheel is returned to its initial position.

Total angular momentum **L** is now **cw** **ccw** **0.**

Was angular momentum conserved between

d & e? Y N

e & f? Y N

d & f? Y N

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