Calculating the Moment of Inertia

What is this about?

You will get to understand more about the idea of rotational inertia by learning how to measure the "moment of inertia (MOI)." The MOI is a numerical measure of the rotational inertia. You will measure the MOI of a meter stick and a baseball bat.

What do I need?

From Sargent-Welch you will need a Moment of Inertia Stick (CP33590-00), Hardwood Meter Stick with Metal Ends(WLS44695), and a BeeSpi Velocimeter (WL2125-X). In addition, you will need a baseball bat, a stopwatch, and a scale to find the mass of the sticks and bat.

What will I be doing?

You will find the time for a meter stick to swing back and forth. You will also time the Inertia Stick in two configurations and the baseball bat. You will use this time to calculate the MOI because the time, T, for an oscillation is related to the MOI by,

$$T = 2\pi\sqrt{\frac{MOI}{mgr_{cm}}},$$

where m is the mass of the swinging object, g is the acceleration due to gravity, and r_{cm} is the distance from the pivot point to the center of mass (CM). The moment of inertia is then,

$$MOI = mgr_{cm}\left(\frac{T}{2\pi}\right)^2.$$

Be sure the mass is in kilograms, the r_{cm} is in meters, and the time is in seconds so that you can use $g = 9.80 m/s^2$.

What do I think will happen?

Take a minute and write down a description of what you think will happen and why you think it. Will the bat or the meter stick have a larger MOI? Why?

What really happened?

1. Hold the meter stick at one end and let it swing. Use the BeeSpi to find the time for an oscillation as shown in the photo. You may want to get several values and average them.
2. Find the mass of the meter stick and the distance to the CM.
3. Calculate the MOI.
4. Repeat these steps using the Inertia Stick with just one mass located at the bottom end.
5. Repeat these steps using the Inertia Stick with just one mass located at the center.
6. Repeat these steps using the baseball bat. You may need to time the oscillations with a stopwatch.

Write a description of your results. Compare the MOI for the bat to the MOI for the meter stick. Compare the MOI for the Inertia Stick with the mass in the two different places.

What did I learn?

You probably noticed that the Inertia Stick had a larger MOI when the mass was closer to the bottom. Rotational inertia depends upon the mass of the object, but also, how far the mass is from the point of rotation. Even though the meter stick is longer than the bat, the bat has more rotational inertia because it is more massive and it has a greater fraction of its mass further away from the point of rotation. A typical value for the MOI of a major league bat is about 0.3 $kg \cdot m^2$.

What else should I think about?

A batter needs to find a happy medium between a bat with a large rotational inertia or large MOI that will hit the ball harder and a bat with a lower rotational inertia or lower MOI that will be easier to swing. Even though most ball players don't realize it, when they are given a new bat, they wiggle it around to get a sense of the location of the CM and they swing it to get a sense of the MOI.

Catch it in the Web!

- Physics and Acoustics of Baseball & Softball Bats by Daniel A. Russell at (http://www.kettering.edu/~drussell/bats-new/bat-moi-details.html)
  A baseball physicist explains the moment of inertia of a baseball bat.

- Sargent-Welch at (http://www.sargentwelch.com/)