# Spinning Sandboxes

## Commentary

An object's resistance to **acceleration** is a measure of its mass, or ***inertia***. Similarly, objects resist ***angular acceleration*** according to their ***moment of inertia***, (or rotational inertia) which depends not only on the mass but also on how that that mass is distributed about an axis of rotation. For example, a figure skater with her arms extended has a greater moment of inertia than one with her arms tucked in close to the body. You will be supplied with a rotating "moment of inertia" base with a string, some weights or washers, a paper clip or mass hanger, a sand pan, some cardboard, tape, and scissors, some sand (1.5 Liters is the recommended quantity), and a stopwatch. You may wish to moisten your sand to make it easier to keep piles in place. Alternatively, this experiment can be interfaced to the computer for data collection, if we choose to do so.

## Inquiry

1. Set up a rotating base as you may have done for an air drag experiment, with the string wound around the spool under the "spider" and the extended portion over a pulley with a weight holder, such as a paperclip at the end. The effect of the weight is to provide a ***torque*** (force times radial distance from the axis) which can cause the base to accelerate as it rotates, while the string unwinds. Place a pan on the spider portion of the base and add a few cups of sand. Adjust the weight so it reaches the floor in several seconds (about 50 grams should work well for the sand portion).

    - What is the relationship between the "falling time" and the moment of inertia?

- Try several different weights (other than fifty grams) and explain how the falling time varies with the amount of applied torque.

2. Confine the sand to one central pile using a taped strip of cardboard. Measure the time it takes the weight to follow a fixed vertical distance. Always keep this distance the same – even though its value is entirely arbitrary.

3. Next, divide the pile in half and place each half on opposite sides of the pan.

   - Does the weight take longer to fall the same distance or less time?

   - What is the ratio of the times? Find a way to relate this ratio to the ratio of the moments of inertia for the two cases.

4. Now divide the piles again so you have four around the perimeter. Never change the total mass of sand in the pan!

   - How does this time compare to that for step #3?

   - How about the moment of inertia?

5. Use more cardboard to make a ring and confine all of the sand to a ring close to the outer rim of the pan.

   - How do results compare to those from steps 3 and 4?

- What conclusions can you draw about the moment of inertia of solid objects from this?

- Try spreading the sand over the entire bottom of the pan. What happens and why? (Make sure to explain all results in terms of the falling time.) The shorter the time, the greater the angular acceleration.

6. **A contest!** The winner is the person or group whose mound is arranged to minimize the time it takes the weight to fall. The only rule is that all competitors must use the same quantity of sand. Which configuration was the speediest and hence, had the smallest amount of inertia?

7. *Extension:* Compare moments of inertia of real objects such as racquets, baseball bats, wood or metal bars, etc. by taping them to the base without the pan and taking ratios of falling times. Note that larger weights (greater than 50 grams) may be required for larger objects. Try taping a long bar or bat to the center of the object and then near the end. For which location is the moment of inertia smaller and why?