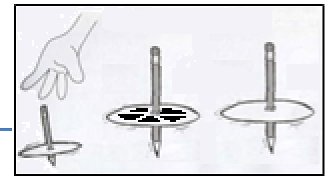
Spin Top Lab Project



Lesson Focus

In this lesson, students build spinning tops out of cardboard, pencils, and hot glue. Their challenge is to design spinning tops that can spin for at least 10 seconds. One is a solid with a circle 25 cm in diameter, one is hollow with a 25cm diameter, the third is a solid with a 10cm diameter.

Objectives

During this lesson, students will:

- Design and build three spinning tops
- Test and refine their designs

Lesson Activities

Students work in teams to design and build their own spinning tops out of everyday materials. Their top must be able to spin for at least 10 seconds with a 25 cm diameter for two of the tops and a 10cm diameter for the third, but groups are encouraged to find ways to make the tops spin for longer. Student teams review their own designs, the designs of other teams, and present their findings to the class.

Angular Momentum (this is in the next chapter)

Angular momentum is a measure of the motion of mass around a center of rotation. It is the product of the mass, velocity and radius of a rotating body. The formula for angular momentum is: L = m x v x r, where m = the mass of the wheel in grams, v = velocity of the rim in meters/second, and r = the radius of the rotating mass. Angular momentum is conserved unless acted on by an outside force. The mass of the top and the distribution of that mass affects the angular momentum of the top. A top will slow down when it is acted on by the forces of friction or gravity. These two forces will eventually cause a top to slow down, wobble and fall over.

Groups are to determine ways to measure or calculate:

	25cm solid	25cm Hollow	10cm Solid
Center of Mass			
Mass of top, m (kg)			
Radius of top, r (m)			
Time of spin (s)			
Moment of Inertia, I ($kg \cdot m^2$)			
Revolutions per second			
Angular velocity, w (rad/s)			
Angular acceleration, α, (rad/s^2)			
Angular Momentum, L ($Kg \cdot m^2/s$) or ($N \cdot m \cdot s$)			
Force applied, f (N)			

Final Report

Written report should include procedures for measuring and calculating parameters listed above and data table of values. An analysis of the three spinning disks and a written explanation of results should be included on why the results were different for each disk.

How to Calculate the Torque Needed to Accelerate a Spinning Disc

Say that a disk has a mass of 30 grams and a diameter of 12 centimeters. It starts at 0 revolutions per second and winds up to about 20 revolutions per second and spins for 10 seconds. What's the average torque needed to create this acceleration? You start with the torque equation:

$$\tau = I\alpha$$

A disk shape rotating around its center, which means that its moment of inertia is

$$I = \frac{1}{2}mr^2$$

The diameter of the disk is 12 centimeters, so the radius is 6.0 centimeters. Putting in the numbers gives you the moment of inertia:

$$I = \frac{1}{2}mr^2 = \frac{1}{2}(0.030\ \text{kg})(0.060\ \text{m})^2 = 5.4 \times 10^{-5}\ \text{kg}\cdot\text{m}^2$$

How about the angular acceleration, α?

$$\alpha = \frac{\Delta\omega}{\Delta t}$$

Here's the angular equivalent of the equation for linear acceleration:

But because the angular velocity always stays along the same axis, you can consider just the components of the angular velocity and angular acceleration along this axis. They are then related by

$$\alpha = \frac{\Delta\omega}{\Delta t}$$

The time,Δt, is 10 seconds, so what about Δw which is w_f-w_i

First, you need to express angular velocity in radians per second, not revolutions per second. You know that the initial angular velocity is 0 revolutions per second, so in terms of radians per second, you get Wi = o revolutions/ sec = o rad//s.

Similarly, you can get the final angular velocity this way:

$$\omega_f = \frac{20\ \cancel{\text{revolutions}}}{1\ \text{s}} \times \frac{2\pi\ \text{rad}}{1\ \cancel{\text{revolution}}} = 40\pi\ \text{rad/s}$$

Now you can plug the angular velocities and time into the angular acceleration formula:

$$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{(w_f - w_i)}{\Delta t} = \frac{(40\pi - 0\pi)\text{rad/s}}{10\ \text{s}} = \frac{40\pi\ \text{rad}}{10\ \text{s}^2} \approx 12.6\ \text{rad/s}^2$$

The angular acceleration is negative because the angular velocity of the disk decreased. The negative acceleration then leads to a reduction in this angular velocity.

You've found the moment of inertia and the angular acceleration, so now you can plug those values into the torque equation:

$$\tau = I\alpha = \left(5.4 \times 10^{-5}\ \text{kg}\cdot\text{m}^2\right)\left(\ 4.0\,\text{s}^{-2}\right) \approx \textbf{2.16e-4}\ \text{N}\cdot\text{m}$$

The average torque is **2.16e-4** N•m

To get an impression of how easy or difficult this torque may be to achieve, you may ask how much force is this when applied to the outer edge — that is, at a 6-centimeter radius. Torque is force times the radius, so

$$F = \frac{\tau}{r} = \frac{\textbf{2.16e-4Nm}}{0.06\ \text{m}} \approx \textbf{0.0036 N}$$

Speeding up the disk doesn't take much force.