Curiosity Guide #901
Angular Momentum
Accompanies Curious Crew, Season 9, Episode 1 (#901)

Phi Top Fun
Investigation #1

Description
Might I introduce you to a really amazing top? You will love spinning this one!

Materials
- Phi Top spinner
- A friend
- A stopwatch

Procedure
1) Show the top to a friend and then lay the top down on its side.
2) Have your friend predict what will happen if you spin the top on the base.
3) Have your friend start the stopwatch as you spin the spinner, using the thumb on one hand and the tip of the index finger on the other.
4) What do you notice? How long does the phi top spin?

My Results

Explanation

The top starts spinning on its edge. Then the top stands up abruptly on its point, which raises its center of mass. The top rotates steadily with very little friction and demonstrates its stability. The stable spinning motion continues for a surprisingly long time as a great visual example of angular momentum.

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Discombobulated Discs
Investigation #2

Description
Let's have a spinner race! Which one will win? Why?

Materials
- 2 weighted discs from a Variable Inertia kit
- Mass scale
- Ramp
- Wood block
- Towel
- A friend

Procedure
1) Ask a friend to compare the two discs.
2) Place each disc on a mass scale and compare.
3) Place one end of the ramp on the wood block and lay the towel on the floor to catch the rolling discs.
4) Place the discs at the top of the inclined plane. Let the discs go at the same time.
5) What do you notice?
6) Switch the places of the discs on the ramp and try the action again.
7) What do you notice this time?

My Results

Explanation
Although the two discs have the same mass, one disc rolls more quickly down the ramp. When the wing nuts are unscrewed, the discs will open. The faster disc has large metal spheres in the center, while the slower disc has the same kinds of spheres around the rim. Whenever mass is further away from the center axis of rotation, there is a greater moment of inertia, so the disc turns more slowly. This is why spinning ice skaters speed up when the skaters bring their arms closer to their bodies and to the center of rotation.

Think about this: Isaac Newton helped us realize that an object moving in a straight path will keep going unless another force acts on it. If the moving object has more mass or is moving with more speed, the object has more momentum and would need a bigger force to stop it. This is true with spinning objects, too, like this top. A twist called torque gets the top to start rotating. We would say that the spinning top has angular momentum and will keep going until another force acts on it.

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Disc Races
Investigation #3

Description
Here's another fun race to try!

Materials
- Ring and Disc Apparatus
- Assorted spheres, discs, and hoops or rings
- Ramp or inclined plane

Procedure
1) Have a friend predict what will happen when a hoop and disc are released at the same time at the top of an inclined plane.
2) Release the hoop and disc at the same time. What happens?
3) What do you think will happen if you use the ring with a small disc or cylinder? Give these objects a try. What happens?
4) Try a small hoop against a larger disc.
5) What do you notice?
6) What would happen if you raced the different discs and rings against a sphere?

My Results

Explanation

Surprisingly, the disc beats the hoop each time, no matter how big the diameter is. How interesting to discover that all the discs roll alike, just as all the hoops roll alike. The spheres roll like one another, too, but the spheres roll faster than the discs and the hoops. The reason the hoops are always the slowest is because their mass is around their periphery or rim, far away from the center axis that is rotating. As a result, the inertia--or resistance to turning-- is greater. In the case of the discs and spheres whose masses are equally distributed throughout, there is still more mass in the center than the mass the hoops have in their centers, so the moment of inertia is lower. Spheres have the lowest moment of inertia and higher translational kinetic energy, so spheres will be quickest of all.

Think about this!   When we think about the momentum of objects traveling straight, we think about their mass and speed. But when we think about angular momentum, we think about how quickly objects are rolling or spinning. We also consider how spread out the mass of each object is, which we call the moment of inertia. Now, if the mass is far away from the center, then the object will roll more slowly. However, when there is more mass toward the center, the angular velocity is faster.

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Speedy Sphere

Investigation #4

Description

Does size matter? Find out!

Materials

- Table
- Ring stand
- Long dowel
- Scissors
- String
- Hoberman Sphere

Procedure

1) Clamp the ring stand on the edge of the table.
2) Slide the clamp up on the ring and secure in place.
3) Fasten the end of the long dowel in the clamp so the dowel extends away from the table.
4) Cut a loop of string and suspend the sphere from its top.
5) Use another loop of long string that connects the top and bottom parts of the sphere and loops back down through the bottom of the sphere.
6) When one string is pulled, the sphere will collapse, and releasing the tension will cause the sphere to expand again.
7) Expand the sphere and give it a rotational push.

8) Ask a friend to predict what will happen if you collapse the sphere while the sphere is spinning.
9) Collapse the sphere during its spin. What do you notice?

My Results

Explanation
When the sphere gets smaller, the sphere speeds up visibly. This is because the expanded sphere has its mass far away from the center of rotation, so the moment of inertia is greater. The sphere resists the angular momentum. As the sphere gets smaller and the mass gets closer to the spinning center, there is less inertial resistance. This is also a great example of conservation of momentum. When inertia is high, velocity is low, but when inertia is low, velocity is high.

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Twist and Spin

Investigation #5

Description

Can you make two spheres spin faster or slower just with a couple of lengths of string?

Materials

- 2 spheres
- String

Procedure

1) Connect the two spheres with a length of string.
2) Hold the string at the center with the two spheres hanging down beside each other.
3) Give each of the spheres a swing around the other and hold your hand steady.
4) What do you notice?

My Results

Explanation

As the string twists and the spheres get closer together, the spheres begin to speed up. As they unwind, the spheres slow down. This is because when there is greater length in the string, the mass is further away from the twisting center, so the moment of inertia is greater. As the length of untwisted string gets shorter, the mass of the spheres is closer to the center, there is less inertial resistance, and the spheres spin faster. This is also a great example of conservation of momentum. When inertia is high, velocity is low, but when inertia is low, velocity is high.

Think about this! The best example of angular momentum is when an ice skater goes into a spin. Imagine that the skater starts the spin with her arms and one leg out from her body. She then slowly begins to turn, but what happens when she brings her leg and arms in? The skater speeds up...**a lot**! At first, the mass of the skater was spread far out, so there was more resistance in turning. The conservation of angular momentum says that when rotating mass is closer to the center, then the object must spin faster. Skaters learn to use the conservation of angular momentum to speed themselves up. Wow! I'd give that a 10!

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Speedy Rotations

Investigation #6

Description

I'm busy getting dizzy! I'm busy getting dizzy!

Materials

- Hand weights
- Rotating platform
- Swivel stool
- A friend

Procedure

1) Place the rotating platform on the floor or use a swivel stool. Make sure there is plenty of open space around the platform.
2) Hold a weight in each hand and carefully step on the platform or sit on the swivel stool.
3) Outstretch your arms to your sides.
4) Have a friend carefully give you a push to start spinning.
5) Slowly bring your arms in toward your body.
6) What do you notice?

My Results

Explanation

At first, you rotate slowly on the stool or platform. However, as you bring your arms into your body, your rotational speed increases. This action demonstrates conservation of angular momentum. The further the weights are from your body, the higher the moment of inertia or resistance to turning. More resistance causes you to rotate more slowly. However, when the weights are closer, inertial resistance goes down, so your speed must go up.

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Spinning Wheel
Investigation #7

Description
Can a wheel help you spin? Try this interesting investigation!

Materials
- Swivel stool
- Bicycle wheel with handle
- A friend

Procedure
1) Have your friend sit on the swivel stool.
2) Challenge your friend to make the stool swivel without using her feet. Could she make the stool turn?
3) Have your friend hold the two ends of the wheel upright.
5) Spin the wheel to get it rotating.
6) Now have your friend turn the wheel to its side.
7) What do you notice?
8) What happens if you rotate the wheel over in your hands, so that the wheel is spinning in the other direction?

My Results

Explanation

When the wheel begins to rotate, the wheel has angular momentum. As soon as the wheel is turned on its side, the angular momentum has changed, and the stool also begins to rotate in the same direction. When the spinning wheel is turned over, the stool stops and reverses direction, again matching the rotational direction of the wheel. If there was no friction in the swivel part of the stool, the stool would rotate at the same speed as the wheel.

Try this at home! You can experience angular momentum yourself. Place a rolling office chair in the middle of the room where there is plenty of space. Find a couple of heavy books and hold one tightly in each hand. Then sit down in the chair and stretch your arms out to the sides. Use your feet to push the floor several times to try to get the chair spinning in place. Once you're rotating, try pulling your arms and legs into the chair. Wow! Stretching out your arms will slow you down, but don't stand up too soon! You might be dizzy!

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Angular Momentum Straw Spinner

STEM Challenge

Description

Your challenge is to create a toy that demonstrates angular momentum. Bet you can't say Angular Momentum Straw Spinner three times fast!

Materials

- Assorted straws
- String
- Yarn
- Scissors
- Washers
- Wooden spool
- Practice golf ball
- Wooden skewers
- Meter stick
- Scotch tape

Procedure

1) Cut a piece of string or yarn one meter long.
2) Choose a weighted object to tie on each end of the string.
3) Thread the loose end of the string through a straw. Use the wooden skewer to push the string through if necessary.
4) Tie the weights on each end.

5) Test the spinner by holding the straw horizontally in one hand and the free end of string in the other. The weighted object should be hanging down.
6) Carefully begin twirling the straw so that the weighted object begins to move in a vertical rotation.
7) What will happen if you begin to pull the string through the straw while the object is spinning?
8) What do you notice?
9) Try the motion again with a short length of string holding the weight. Then lengthen the string while the object is rotating.
10) What do you notice this time?
11) Record any adjustments you made to your toy in the My Results section.

My Results

Explanation

As you pull the string into the straw, the rotating object begins to spin faster. The toy demonstrates conservation of angular momentum. The further the weight is from the center of rotation, the higher the moment of inertia, or resistance to turning. This causes the object to rotate more slowly. However, when the string is shorter and the weight is closer to the center opening of the straw, inertial resistance goes down, and the speed of the moving object must go up.

Try this at home in your yard! Have you ever tried to flip a bottle to land it on its base? This is difficult if the bottle is full because the bottle will rotate quickly. The trick is to empty the bottle, so that the bottle is only $\frac{1}{4}$ or 1/3 full. Now, when you flip the bottle, some of the water flows to each end, and when that happens, the mass spreads out and slows the bottle down during the rotation. Not only is this a fun outdoor activity, but also a great example of the conservation of angular momentum!

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