The Science of Rotation

January 15 – May 15, 2010

Educator Materials

Presented by:

Lied Discovery Children's Museum

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Las Vegas, NV 89101
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Call 702.382.3445
For Field Trip Information

Spin! The Science of Rotation is an interactive exhibit designed and produced by the *Catawba Science Center*.

Educator Materials

What's included in this packet?

Included in this packet is an overview of the temporary exhibit ***SPIN! The Science of Rotation***. We have outlined the intended educational goals, connections to *Nevada Content Standards*, suggested classroom activities, and a list of additional resources to further your exploration of forces and motion.

We want to make it easy for you to connect the content of ***SPIN! The Science of Rotation*** with what is happening in your classroom- so if you have additional questions about structuring your visit, please calls us at 702.382.3445.

Note to teacher and group leaders

These materials are especially designed for teachers and group leaders preparing to bring students to see ***SPIN! The Science of Rotation*** at Lied Discovery Children's Museum. The exhibit is recommended for youth grades 1-8 and teachers/group leaders are encouraged to customize the information provided in this packet to meet the individual needs of their students.

Pertinent connections between exhibition content and Nevada Content Standards have been outlined so that the educational goals of the exhibition may be incorporated into lesson plans.

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SPIN Exhibit Overview & Goals

SPIN! The Science of Rotation is a hands-on exploration of ***forces and motion*** Visitors can experiment with concepts such as force, inertia, distance, speed, and other variables that impact rotational motion.

Educational Goals

Visitors will…

- Increase understanding of forces and motion.
- Increase interest in scientific inquiry and experimentation.
- Increase comfort engaging in scientific inquiry and experimentation.
- Enjoy exploring forces and motion using hands-on activities.

Big Idea(s)

- Our world is full of things that spin!
- Scientists investigate the behavior of a spinning object by looking closely at its weight, shape, speed and the forces acting on it.

Guiding Questions

These guiding questions can be used before, during or after your visit. Guiding questions are great tools for sparking discussions about the topics being explored. Teachers and chaperones can use these to engage youth in focused conversations about the ***forces and motions*** principles being explored in the gallery (*See Chaperone Guide).*

1st -2nd Grades

- What can you tell me about the materials you are using (shape, weight, texture, size)?
- What is the same and different about the materials you are using?
- What did you notice/see when you did that?
- Did anyone notice anything else happening?
- Can you make that object move? Stop? Change direction?
- How fast or slow are things moving? Why do you think that happens?
- What do you think, or predict, will happen?

3rd -5th Grades (use questions listed above plus…)

- Did anyone notice any patterns in the movement?
- What do you think changed the object's motion?

6th -8th Grades (use questions listed above plus…)

- What can you tell me about forces and motion?
- What forces can we observe with these activities?

SPIN Common Misconceptions

Lots of people have misconceptions when it comes to science principles. For ***forces and motion*** the following have been identified by the *Association for the Advancement of Science* (1993, 2009). Before, during and after your visit to ***SPIN! The Science of Rotation***, you may hear some of these ideas from your students. Educators are highly encouraged to explicitly address misconceptions. Host open discussions or engage in activities that support exploring the "mis"-connections students are making between ideas, and facilitate re-directing students towards accurate understandings.

The concept of force

Students hold various meanings for the word "force." Typically, students think force is something that makes things happen or creates change. Their descriptions of force often include related words such as energy, momentum, pressure, power, and strength. Younger students associate the word "force" with living things (Watts, 1983b).

Students tend to think of force as a property of an object ("an object has force," or "force is within an object") rather than as a relation between objects (Dykstra, Boyle, & Monarch, 1992; Jung et al., 1981; Osborne, 1985). In addition, students tend to distinguish between active objects and objects that support or block or otherwise act passively. Students tend to call the active actions "force" but do not consider passive actions as "forces" (Gunstone & Watts, 1985).

Newton's laws of motion

Students believe constant speed needs some cause to sustain it. In addition, students believe that the amount of motion is proportional to the amount of force; that if a body is not moving, there is no force acting on it; and that if a body is moving there is a force acting on it in the direction of the motion (Gunstone & Watts, 1985). Students also believe that objects resist acceleration from the state of rest because of friction—that is, they confound inertia with friction (Jung et al., 1981; Brown & Clement, 1992).

Research has shown less success in changing middle-school students' ideas about force and motion (Champagne, Gunstone & Klopfer, 1985). Nevertheless, some research indicates that middle-school students can start understanding the effect of constant forces to speed up, slow down, or change the direction of motion of an object. This research also suggests it is possible to change middle-school students' belief that a force always acts in the direction of motion (White & Horwitz, 1987; White, 1990).

Students have difficulty appreciating that all interactions involve equal forces acting in opposite directions on the separate, interacting bodies. Instead they believe that "active" objects (like hands) can exert forces whereas "passive" objects (like tables) cannot (Gunstone & Watts, 1985). Alternatively, students may believe that the object with more of some obvious property will exert a greater force (Minstrell, 1992).

Citation: American Association for the Advancement of Science (AAAS) (1993, 2009). *Benchmarks Online*. Retrieved March 24, 2011, from Project 2061 Web Site: www.project2061.org/publications/bsl/online/

spin **EXHIBIT COMPONENT DESCRIPTIONS**

Spin! The Science of Rotation is an exciting exhibit that explores the fun… AND the science of objects that rotate. Using interactive exhibits and real-life examples, students will design experiments to explore the science behind spinning toys, sports, transportation, space travel, entertainment — and even the universe itself.

Spin offers 14 unique exhibit areas, including:

Let It Roll

There are two parallel tracks sloping down, then back up. Visitors are encouraged to race disks along the tracks. Although the disks have the same mass, one of the disks is hollow and one is solid, and as a result, they roll differently.

Weighted Wheels

The visitor spins two heavy wheels with the same size and weight, but different weight distributions. The visitor can compare how much force it takes to start each wheel spinning, how long each wheel continues to spin, and how easy it is to make each wheel stop spinning.

Fast Lane

There is a large disk that spins continually. A small car (with a speedometer) rides on top of this spinning wheel. The car can be pulled out on an adjustable radial arm to ride near the outside edge of the wheel, or pushed toward the middle to ride near the center of the wheel. Visitors observe the car's speedometer to see that the car travels faster at the edge of the wheel than it does near the center.

Pit Stop

There are two parallel tracks. Visitors can change the wheels and adjust weights on two similar toy cars. Visitors are encouraged to race the two cars to observe the effects of wheel size and weight on speed.

Racing Rollers

Visitors roll a pair of double cones down two parallel ramps made of a series of segmented tracks. The track segments are movable and interchangeable so the participant can adjust their sequence. With experimentation, the visitor can discover how the tracks affect the speed of the cones.

Dynamic Dots

A laser light beam rotates inside enclosed screens, projecting dots of light onto the screens. The visitor can adjust the location of the laser to discover that the projected dot of light moves faster when the screen is far away and moves more slowly when the screen is closer.

Air Thrusters

Air travels through a T-shaped tubing system. The visitor can change the orientation of the tubing arms to adjust the direction of the escaping air and affect the speed and direction of rotation.

Build A Top

This table includes disks of different sizes that visitors can use to build a variety of tops. Multiple visitors can experiment to compare the rotation of tops with different shapes and weights.

Coriolis Fountain

Visitors spin an exhibit that shoots out water jets. The water streams curve as they fall, demonstrating the Coriolis effect.

Laser Show

A laser reflects off of internal rotating mirrors. Visitors can adjust the speed of the mirrors to change the appearance of the projected laser beams, creating their own mini laser show.

Spin Speed

Visitors are encouraged to sit in a tilted chair that rotates. Visitors can adjust their weight distribution to affect the chair's rotation.

Human Centrifuge

Up to four visitors sit in a large tub with their backs against the wall of the tub. When they push against a fixed wheel in the center, the entire tub rotates. The visitors feel the effects of inertia when they are pinned against the outer wall of the tub.

Fluid Centrifuge

Visitors turn a crank, which rotates a flat rectangular transparent chamber filled with colored liquid. As the chamber turns, the liquid rises along the outer walls of the chamber, forming the shape of a parabola.

Speed Limit

The visitor cranks a handle, which turns a blower to make air travel through a pipe. The moving air turns an anemometer, which measures the speed of the air. As the visitor cranks faster, governor arms rise upward and outward, activating an air output valve. This acts to limit the amount of air that can enter the pipe, and thus regulate the speed of the anemometer.

SPIN CURRICULUM LINKS

SPIN! The Science of Rotation is not only fun, but also a resource to support classroom learning. ☺ The following National and State standards are explored within the exhibition.

K-12 NEVADA CONTENT STANDARDS

Grades K-2

P.2.B Students understand that position and motion of objects can be described.

P.2.B.1 Students know the position and motion of an object can be changed by pushing or pulling. E/S

P.2.B.2 Students know things move in many different ways and at different speeds (e.g., straight line, zigzag, vibration, circular motion, fast/slow) E/S

Grades 3-5

P.2.B Students understand that forces can change the position and motion of an object.

P.2.B.1 Students know that when an unbalanced force is applied to an object, the object either speeds up, slows down, or goes in a different direction. E/S

P.2.B.2 Students know how the strength of a force and mass of an object influence the amount of change in an object's motion. E/S

Grades 6-8

P.2.B Students understand that position and motion of an object result from the net effect of the different forces acting on it.

P.2.B.1 Students know the effects of balanced and unbalanced forces on an object's motion. E/S

NATIONAL BENCHMARKS FOR SCIENCE LITERACY, AAAS

Scientific Inquiry

K-2 People can often learn about things around them by just observing those things carefully, but sometimes they may learn more by doing something to the things and noting what happens.

The Mathematical World

K-2 Sometimes changing one thing causes change in something else. In some situations, changing the same thing in the same way usually has the same result.

Scale

K-2 Things in nature and things people make have very different sizes, weights, ages and speeds.

The Physical Setting

3-5 Changes in speed or direction of motion are cause by forces. The greater the force is, the greater the motion will be. The more massive an object is, the less effect a given force will have.

spin PRE AND POST-VISIT ACTIVITIES

Before and after your visit, explore ***forces and motion*** in your classroom. Below is a selection of activities we think are fun and educational.

To enhance your experience try:

- **1st- 2nd GRADES**

Chorus Line [Pre-visit activity] 15-20 min
Key take-away: The speed of any particular point on a rotating object depends on the point's distance from the axis of rotation.
Exhibit connection(s): *Fast Lane*

Salad Spinner Art [Post-visit activity] 15-20 min
Key take-away: Newton's first law of motion, an object in motion will continue in motion in a straight line unless acted upon by a force.
Exhibit connection(s): *Human Centrifuge, Fluid Centrifuge*

- **3rd – 5th GRADES**

Rotational Inertia Derby-Rolling Cans [Pre-visit activity] 25-30 min
Key take-away: The speed and distance that objects move depend on their weight distribution, the viscosity of their contents, their radii, their mass, and many other factors.
Exhibit connection(s): *Let It Roll, Weighted Wheels, Spin Speed*

Spinning Water Buckets [Post-visit activity] 25-30 min
Key take-away: Newton's first law of motion, an object in motion will continue in motion in a straight line unless acted upon by a force.
Exhibit connection(s): *Fluid Centrifuge, Human Centrifuge*

- **6th-8th GRADES**

Weighted Inertia Rods [Pre-visit activity] 25-30 min
Key take-away: A spinning object's angular momentum depends on the speed of rotation, the object's mass, and how the mass is distributed.
Exhibit connection(s): *Let It Roll, Weighted Wheels, Spin Speed*

Spinning Water Buckets [Post-visit activity] 25-30 min
Key take-away: Newton's first law of motion, an object in motion will continue in motion in a straight line unless acted upon by a force.
Exhibit connection(s): *Fluid Centrifuge, Human Centrifuge*

Helpful SPIN Terms

Acceleration: The change that occurs in an object's speed or direction during a certain period of time. This can be either an increase or decrease in speed; *change* is the key word here.

Angular Momentum: An object's tendency to keep spinning in the same direction. A spinning object's angular momentum depends on the speed of rotation, the object's mass, and how the mass is distributed. It can also be defined as an object's rotational inertia multiplied by how fast it spins.

Axis of Rotation: The imaginary line around which a rotating object spins. For example, the earth rotates around an axis running between the North and South Poles.

Centrifugal "Force": (Center Fleeing Force) Term often used to describe the sensation of being pushed or pulled outward from the center of a rotating object. In fact, what's going on is actually a result of inertia—a moving object's tendency to keep moving in a straight line. For example, if you are riding in a car and the driver suddenly takes a left turn, you feel as though you're being pushed to the right side of the car. What really happens is your body continues in a straight line, while the side of the car gets in your way, causing you to press against it. Centrifugal "Force" is not a true force; it is more accurate to describe it as the result of a moving object's inertia.

Centripetal Force: (Center Seeking Force) A force that pushes or pulls an object towards the center of its rotational axis, thus keeping the object in rotation. For example, the moon stays in orbit because Earth's gravity provides a centripetal force on the moon. Without this force, the moon would fly off into space in a straight line.

Force: A push or a pull that can impose a change of motion on an object. This concept first appeared in Newton's second law of motion, and is usually expressed by the equation: Force = Mass X Acceleration.

Inertia: The tendency of an object to resist a change in its state of motion. According to Isaac Newton's First Law of Motion, an object at rest remains at rest and an object in motion remains in motion in a straight line *unless acted on by a force.* This tendency of an object to keep doing what it is already doing is called inertia.

Momentum: Any mass that is in motion has momentum. In fact, momentum depends upon mass and velocity—the amount of matter that is moving and how fast it is moving. A roller coaster moving at a high speed has a lot of momentum. A tennis ball moving at a high speed has less momentum. The building you are in, despite its large mass, has no momentum, since it is at rest.

Rotational Inertia: The tendency of an object to resist a change in its state of rotation. It is an object's ability to keep spinning at the same speed and in the same direction, or an object's ability to resists spinning if it isn't spinning already.

Torque: The measure of the force applied to an object to produce rotational motion, usually measured in foot-pounds. Torque is determined by multiplying the applied force by the distance from the pivot point to the point where the force is applied.

Additional Resources

Books

Cassidy, John. Explorabook. Palo Alto, CA: Klutz Press, 1991.

Cunningham, James B. Hands-On Physics Activities with Real-Life Applications. San Francisco: Jossey-Bass, 1994.

Gonick, Larry and Art Huffman. The Cartoon Guide to Physics. New York: Harper Perennial, 1991.

Hewitt, Paul G. Conceptual Physics. San Francisco: Addison Wesley, 2005.

Tolman, Marvin N. Hands-on Physical Science Activities. West Nyack, NY: Parker Publishing Co., 1995.

Zubrowski, Bernie. Tops: Building and Experimenting with Spinning Toys. New York: William Morrow and Company Inc, 1989.

Web Sites

"Centripetal Force and Centrifugal Force." [Online] Available http://www.infoplease.com/ce6/sci/A0811114.html)-Columbia, May 2007.

"Centripetal Force—The Real Force." [Online] Available http://regentsprep.org/Regents/physics/phys06/bcentrif/default.htm, May 2007.

Idaho State University Department of Physics. "Demonstration Road Show." [Online] Available http://www.physics.isu.edu/~shropshi/fmdesc.htm, May 2007.

Sonoma State University. "Newton's First Law Teacher Information." [Online] Available http://swift.sonoma.edu/education/newton/newton_1/html/newton1.html, May 2007.

American Association for the Advancement of Science (AAAS) (1993, 2009). *Benchmarks Online*. Retrieved March 24, 2011, from Project 2061 Web Site: www.project2061.org/publications/bsl/online/

spin Chaperone Guide

Welcome to the Museum!

These guiding questions can be used during your visit. Guiding questions are great tools for starting discussions about the topics being explored. Use these to engage youth in focused conversations about the ***forces and motions*** principles being explored in the gallery.

1st -2nd Grade

- What can you tell me about the materials you are using (shape, weight, size)?
- What is the same and different about the materials you are using?
- What did you notice/see when you did that?
- Did anyone notice anything else happening?
- Can you make that object move? Stop? Change direction?
- How fast or slow are things moving? Why do you think that happens?
- What do you think, or predict, will happen?

3rd -5th Grades

Use *K-2 Guiding Questions* plus…

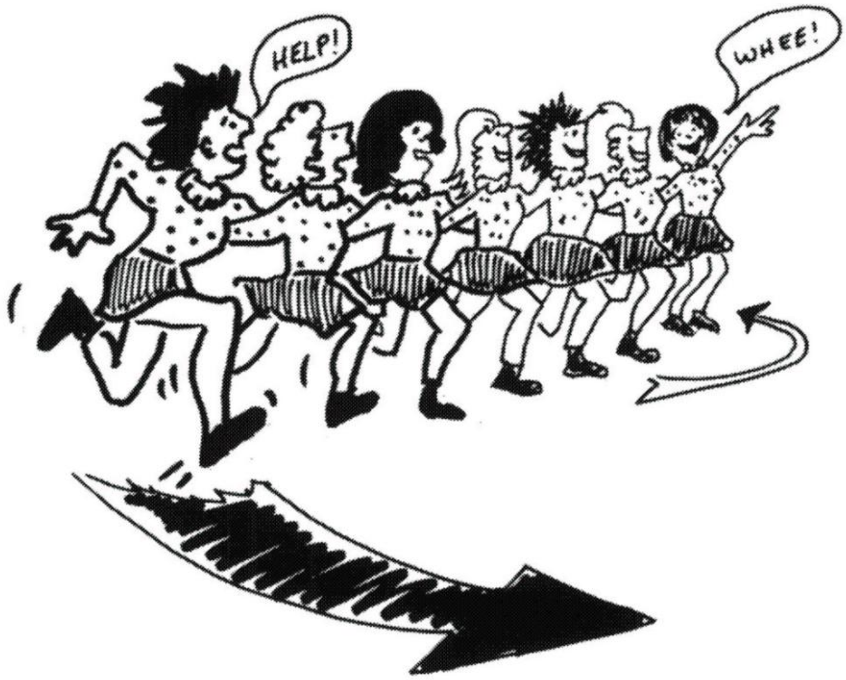
- Did anyone notice any patterns in the movement?
- What do you think changed the object's motion?

6th -8th Grades

Use *K-2 & 3-5 Guiding Questions* plus…

- What can you tell me about forces and motion?
- What forces can we observe with these activities?

Chorus Line



Summary: When a straight line of volunteers spins in a circle, the person farthest from the center of the circle must move fastest in order to keep the line straight. This demonstrates that the speed of any particular point on a rotating object depends on the point's distance from the axis of rotation.

Science Content/Background:

Points toward the center of the circle have to travel only a short distance during one revolution. Points on the outside edge must travel a much greater distance during the same revolution. The circumference of the circle increases as the radius of the circle increases, so points further from the center of the circle have further to travel in the same period of time.

Related Exhibits:	*Fast Lane*
Time:	15-20 min
Age:	1st – 2nd grades
Safety Issues:	This is a kinestic activity, so it requires a large open space for movement, and attention to how fast the students are moving.
Materials:	Optional: Broom handle or long pole, Tape Measure, Stopwatch

Procedure**:**

spin

Real Time:

1. Break class up into groups of 6-10. (Depending on space available).

2. Ask them to stand shoulder to shoulder as if in a chorus line, and to put their arms around the waists/shoulders of their neighbors to form one long connected line.

3. Choose on one end of the line to be the "spinner", explain that their job is only to spin, keeping themselves in the same spot, bringing everyone else with them.

4. Instruct the "spinner" to start spinning. Challenge the line to stay straight as they move. Ask students what they observe? Is everyone moving the same? Repeat the test a few more times, until the entire group has made it back to their original starting point.

5. Have students share their observations of the speed and effort they each needed to exert. Record their data. You may elect to have students rate their speed on a scale of 1-5, 1= fast/lots of effort, 5=slow/very little effort. What does the data find? Compare data from the innermost part of the circle (the "spinner") to farthest from the center of the circle (the outer edge).

6. Switch the positions and repeat the exercise. Ask them to describe their observations again.

7. Ask students if they can think of any other situations where they have observed the same kind of thing. Students may suggest car racing, horse racing, track meets, etc. Explain that what they have just uncovered an idea about motion that we experience everyday and studying this concept helps us better understand how other things move, like the Earth in space.

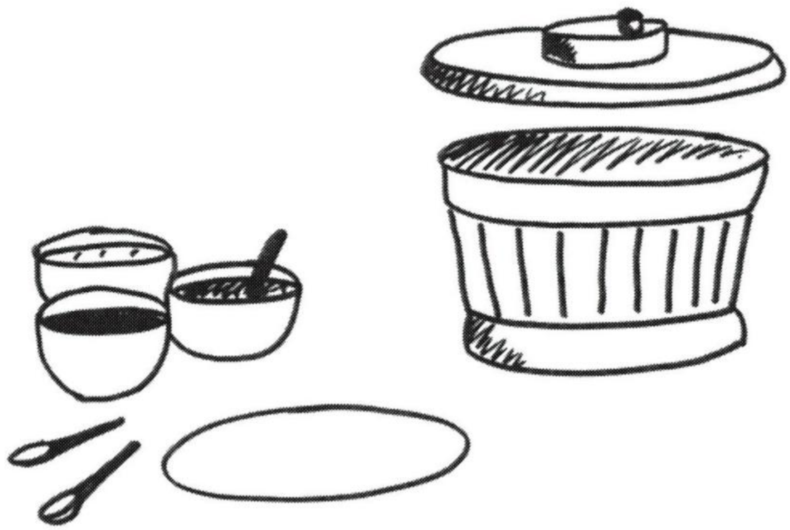
8. Ask students why this concept helps us better understand the Earth? Students should suggest because like how they moved in a circle, the Earth is a sphere. And like how they had a spinner, the Earth spins on an axis or rotates.

Extensions:

If they are having a hard time keeping the line straight (especially with younger children), you can have them hold on to the broom handle or pole as they rotate.

To incorporate math for older students, measure the distance from the outermost volunteer to the center of rotation and multiply by 2 π to determine the circumference of the circle, or the distance that this volunteer needs to travel. Time how long it takes the group to make a complete rotation, and use this data to calculate the volunteer's rate (Rate = Distance / Time). Repeat this process for a volunteer standing closer to the center of rotation. Who has to travel further in the same amount of time? How much faster does the first volunteer need to go in order to complete the greater distance in the same amount of time?

Salad Spinner Art



Summary: Use a salad spinner and paints to create colored patterns.

Science Content/Background:
According to Isaac Newton's First Law of Motion, an object in motion will continue in motion in a straight line unless acted upon by a force. The paint travels in a straight line once it is set in motion, which results in colorful designs. The paint does not continue in a straight line indefinitely because it is slowed by friction with the paper and ultimately stopped by the edge of the salad spinner.

Related Exhibits: Human Centrifuge, Fluid Centrifuge
Time: 15-20 min
Age: 1^{st}- 2^{nd} grades
Safety Issues: Use non-toxic washable paints.
Materials: Salad spinner
Paper discs sized to salad spinner basket, paints, droppers or spoons, Glitter (optional), cookie tray, sponges for cleanup
Optional: Food Coloring, different kinds of paints and paper

Preparation:
- Cut paper to fit into the bottom of the salad spinner.
- Place spinner on top of cookie tray to catch leftover paint.

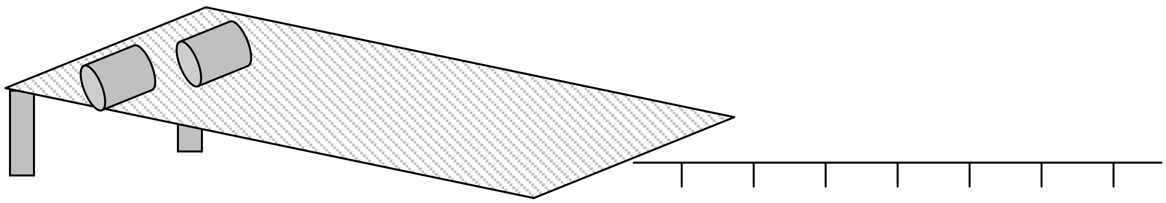
Procedure
1. Ask students what they remember about their trip to ***SPIN! The Science of Rotation.*** What were some of the science ideas they remember? What's one new idea they learned? Record and discuss responses.
2. Share with students the big idea(s) of ***SPIN!***

- Our world is full of things that spin!
- Scientists investigate the behavior of a spinning object by looking closely at its weight, shape, speed and the forces acting on it.

3. Explain to students that they are going to explore another science idea about forces and motion.
4. Demonstrate the painting activity.
   a. Drip paint onto the paper with a spoon or dropper. Try using two or three different colors.
   b. Place the lid on the spinner and spin for about thirty seconds.
   c. Open the spinner to discover your creation. Try sprinkling glitter on the wet paint.
5. Ask each student to do the painting activity, while being sure to make observations about what happens to the paint. What is it doing?
6. While waiting for everyone to make a painting, ask students to hypothesize why the paint moved the way it did? Why did it create the image they see on the paper?
7. As a whole group, discuss students' hypotheses. Students may suggest ideas about spinning, re-introduce the concept of rotation. Students may also suggest ideas about hitting the salad spinner, re-introduce the concept of force. Explain that while the spinner was pushing the paint away from the center moving in a straight line, while the outer edge of the bowl was also pushing the paint back in, making the movement stop.
8. Introduce Newton's Laws of Motion. Ask students which laws they think they observed during this activity.

Extensions:
Experiment with the concept by changing variables. Try spinning for different amounts of time. Does this affect your design? Try dripping paint onto only one quarter of the paper disk. Does the paint spread in a circle, or does it stay in the same quadrant? Try same activity with food coloring instead of paint.

Rotational Inertia Derby: Rolling Cans



Summary: Students roll different kinds of soup cans down ramps to determine how the contents of the can affect how fast it rolls.

Science Content/ Background:
The speed and distance that objects move depend on their weight distribution, the viscosity of their contents, their radii, their mass, and many other factors. One important factor is how freely the contents move within the can. With cans of very runny soups, like tomato soup, the can itself may rotate while the contents remain more stationary. This can cause friction between the soup and the inner walls of the can. Different soups have different amounts of internal friction. Thick soups (ex: cream of mushroom) usually rotate along with the can, as one solid body.

Related Exhibits: Let It Roll, Weighted Wheels, Spin Speed,
Time: 25-30 min
Age: 3rd- 5th grades
Materials: 3 Race Track Boards, propped on books or cement blocks at an equal height, 3 (same-size) cans of each of 3 soups:
(1) tomato soup or broth
(2) cream of mushroom soup
(3) chunky minestrone or vegetable beef soup
Optional: Tape measure, stop watches, masking tape, many more food cans of varying can sizes and soup or food types

Procedure:
Preparation:
1. Divide your group into three teams. Have each team set their board on the block to prepare their racetrack. Make sure all tracks start at the same height.

2. Give each team a set of three soup cans (runny, creamy and chunky). Have them hypothesize which soups will roll fastest, and explain why. Record predictions.

Testing predictions:
1. Each team should choose cans #1 and #2 for their first trial. At the signal, teams roll the two cans down the tracks, watching closely to determine the winner. Repeat this race three times to confirm the winner.

2. Repeat with cans #2 and #3. Repeat this race three times to confirm the winner.

3. Repeat with cans #1 and #3. Repeat this race three times to confirm the winner.

4. Determine the overall winner of the races.   Was it what they predicted? Did all teams have the same results? Discuss. Can they think of a way to explain why the winning can rolled fastest?

Extensions:

1. Use a tape measure and masking tape to mark out a distance of 5 feet (in 6 inch intervals) from the foot of the ramp. Repeat the experiment, but rank the cans according to *distance* rolled instead of speed. Compare these results with your previous trials: do the *fastest* cans roll *furthest*?

2. Experiment with more different types and sizes of canned goods—stews, meats, hash, juices, soft drinks, full and empty cans, etc. Try to determine:

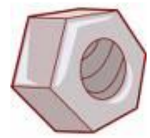
- Which roll *faster/further*: big cans or small cans of the same kind of soup? Why do you think so?
- Which rolls *faster/further*: heavier cans or lighter cans of the same size? Why do you think so?
- For the same size cans, which roll *faster/further*: cans of thick soup, cans of broth, or cans of chunky soup? Why do you think so?
- Which rolls *faster/further*: full cans or empty cans of the same size? Why do you think so?
- Do cans that roll faster always roll further?
- Which kinds of cans (cans of thick soup, cans of broth, or cans of chunky soup) roll the *straightest*, and which cans *wobble* as they roll?

3. Use stop watches to measure the exact time it takes for each type of can to roll down the track. Try it three times and take an average. Measure the distance of the ramp and divide this distance by the average time to calculate the velocity of the rolling can.

4. Cover the ramps with carpet or fabric to change the surface that the cans roll on. Repeat the trials for velocity and for distance. How does a higher-friction surface affect the cans' rolling?

Weighted Inertia Rods





Summary: Spin a series of weighted yardsticks to compare the effect of weight position on each yardstick's rotation.

Science Content/Background:
A spinning object's angular momentum depends on the speed of rotation, the object's mass, and how the mass is distributed.

Each yardstick has a different weight distribution. Yardsticks with most of their mass further from the axis of rotation are harder to start spinning, but once they are spinning they will spin for longer than yardsticks with more of their mass concentrated around the axis of rotation.

Spinning any yardstick from its center hole establishes a shorter radius than spinning the yardstick from the hole at one end. As a result, it feels different to spin yardstick #3 from its center hole than it does from its end hole.

For the same reason, it feels different to spin both yardsticks #2 and #3 from their center holes—although they have the same mass, the weights are closer to the axis of rotation for yardstick #2 than they are for yardstick #3.

The symmetry of weight distribution also affects how the yardsticks spin. For example, yardstick #5 is difficult to spin from its center hole because the weight is unbalanced, thus creating a wobble when it is spun.

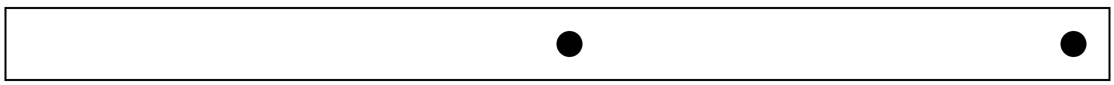
Related Exhibits:	*Let It Roll, Weighted Wheels, Spin Speed*
Time:	25-30 min
Age:	6^{th}-8^{th} grades
Safety Issues:	Establish a safety zone around the stick spinner to prevent accidents. If students are shorter, the end of the yardstick will hit the floor when it spins. Taller students should watch for ceiling collisions.
Materials:	7 yardsticks, duct tape, pencils, drill and drill bit to make pencil-sized hole, 9 hex-nuts to fit a 1 inch bolt (item #135941 at Lowes) Optional: additional yardsticks and nuts

Procedures:

Preparation:
Make a set of six weighted yardsticks according to the following instructions.

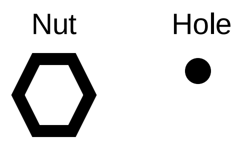
1. Wrap duct tape around the eraser end of the pencil until it forms a cap on the end that will prevent the pencil from sliding.

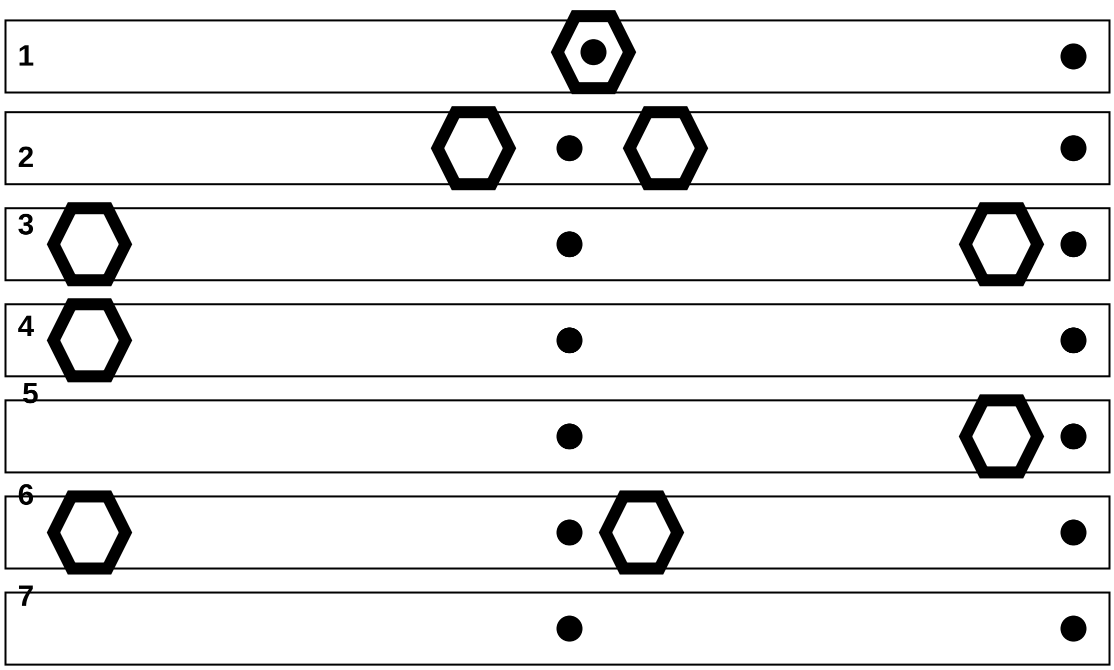
2. Find a drill bit with the same diameter as a pencil. Drill a hole in the center of each yardstick and another hole ¾ inch from one end of each yardstick (see below).



3. Number the yardsticks 1 through 7. This will make discussion easier later on.

4. Use duct tape to attach hex-nuts to the yardsticks as follows:





Testing Ideas:
1. Have each yard stick set up as a testing station around the room.

2. Divide students into small groups. Explain that they will be investigating movement and visiting seven stations, conducting experiments, analyzing data collected from their testing and drawing conclusions about what they observed.

3. Demonstrate testing procedure to the whole group.
   a) Insert a pencil through the *center* hole in rod each. Make sure the taped pencil end is big enough that the yardstick will not slide off the pencil while it is spinning.
   b) Hold the pencils and out in front of them so that the yardstick can swing freely.
   c) Start the yardsticks spinning, paying attention to how the spinning feels.
   d) Repeat the test only this time, remove the pencils from the center holes and insert into the holes at the *ends* of the yardsticks.

4. Have groups try each station.

5. Have groups discuss and interpret their observations. Which yardsticks were easiest to spin? Which were hardest? Which spun smoothly and which had a more irregular spinning pattern? Were the yardsticks that were hard to spin using the center hole also hard to spin using the hole at the end of the yardstick? Record ideas.

6. As a whole group, have students suggest conclusions/reasons for what they observed, describing the spinning of different weighted inertia rods.

Extensions:
Try making additional weighted inertia rods by moving the weights into new positions. Before your volunteers spin the yardsticks, have them predict how they will spin based on their earlier observations and generalizations.

Try holding the end of each yardstick in your hand, then spinning it without using the pencil. How does it feel different?

Spinning Water Bucket

Summary: Visitors will be amazed that they stay dry while spinning a bucket of water over their heads.

Science Content/Background:
According to Isaac Newton's First Law of Motion, an object in motion will continue in motion in a straight line unless acted upon by a force. The bucket is unable to travel in a straight line because it is attached to the rope (which provides centripetal force, or center seeking force), so it swings in a circle instead. The water in the bucket is unable to travel in a straight line because it is stopped by the sides of the bucket. Therefore, as the bucket spins, the water remains inside.

Related Exhibit:	*Fluid Centrifuge, Human Centrifuge*
Time:	25-30 min
Age:	3rd -5th & 6th – 8th grades
Safety Issues:	Give yourself enough overhead space and distance to spin without hitting anyone. Practice in a safe place first.
Materials:	Needed: Bucket with a strong handle, 3-foot length of rope, jug of water Optional: Plexiglas spinning platform, clear glass or plastic cup, wine glass, food coloring

Procedure:

Preparation:
1. Tie a rope to the bucket handle with a firm reliable knot.

2. Fill the bucket partway with water (about 1/3 full).

3. Be sure area above and around you are clear. Water will slosh out if your bucket gets bumped in mid-swing.

4. Practice (outside!) before you do this experiment in front of the group. Start the bucket swinging gently from side to side, gathering speed. When you feel confident, swing the bucket up and over your head, and keep swinging it in circles in front of you, quickly enough that it makes it over the top of the swing without wobbling.

5. Practice starting and stopping, and experiment with how fast and how slow you can swing the bucket.

Guiding the group:

1. Be sure area above and around you is clear.

2. Ask a volunteer to inspect the bucket to be sure that it is an ordinary container.

3. Pour water into the bucket until it is about 1/3 full.

4. Ask students to predict what will happen if you spin the bucket over your head so that it goes upside down.

5. Spin the bucket over your head. If you feel comfortable, allow a volunteer to try.

6. Ask the group for explanations as to why the water did not fall out of the bucket.

7. Record ideas.

8. Explain that according to Isaac Newton's First Law of Motion, an object in motion will continue in motion in a straight line unless acted upon by a force. Can they think of any everyday examples of this law?

9. Ask students to describe what direction the bucket is traveling. They should describe in a circle instead of a straight line.

10. Explain that the bucket is unable to travel in a straight line because it is attached to the rope (which provides centripetal force, or center seeking force), so it swings in a circle instead. The water in the bucket is unable to travel in a straight line because it is stopped by the sides of the bucket, a force. Therefore, as the bucket spins, the water remains inside.

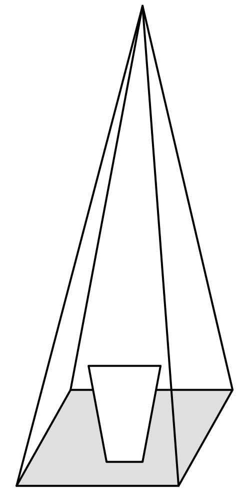
Extensions:

What would happen if you let go of the rope in mid-swing? (Try it outside!)

Try getting the bucket swinging in a circle that is parallel to the floor. You'll have to start it swinging in front of you, perpendicular to the floor, and change the axis of rotation in mid-swing. This is difficult, but your audience will be delighted.

Instead of a bucket, try the Plexiglas spinning platform (provided). Practice until you can swing it in a smooth arc. Then set a clear cup ½ filled with colored water on the platform. Spin the platform: the cup doesn't fall off the platform, and no water spills out. Try a water glass. Try a wine glass. Remember to be safe.

Similarly, the Plexiglas spinning platform cannot travel in a straight line because it is attached to the ropes. The glass on the platform cannot travel in a straight line because it is stopped by the platform. The water in the glass cannot travel in a straight line because it is stopped by the sides of the glass. Therefore, as the platform spins, the water remains in the glass and the glass remains on the platform.



Another explanation: if you were to let go of the rope at any point in the swinging arc, the bucket would travel in a straight line *in the direction is traveling as it is released*. Essentially, the bucket would travel off in a direction that is *tangential* to the circle at the point is released (see diagram). If Bucket A were released, it would continue to travel along Line A. At any point in the circle, the water is also moving along the same tangent, but it is the side of the bucket that keeps it from traveling further. The water in Bucket A is traveling in the direction of Line A, but the side of the bucket keeps from splashing out.