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**Bed of Nails - Science of the Circus**

**Setup**

- Connect two pieces of the bed of nails on the floor.
- Blow up balloons
- Place out the two smaller boards, one with a single nail and one covered in the nails.

**Experiment**

1. Show your audience that the nails are sharp by easily popping the balloon with the board having the single nail
2. Now, blow up another balloon and place it on the bed of nails. Press down hard to show the balloon will not pop.
3. If any guests are feeling brave, they may test out the full size bed of nails. First, have them sit lightly, and then slowly lean back until they are lying flat on their back. Do not allow guests to lie down face first, or on their side.

**How Does It Work?**

When you pop the first balloon with the nail, all of the pressure is concentrated on one point on the balloon so the balloon easily pops. When you place the balloon on the bed of nails, the pressure points are spread all across the surface of the balloon.

Just like the balloon, when a person lies on a bed of nails, their body is evenly distributed across the surface of the nails. The only real danger of being punctured by a nail is if the performer doesn't lie down or get up correctly and pressure points of the nails are concentrated on one area of the body. Now you know the circus secret!

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**Deep-Frying Science**

**Objective**
Understand the science behind deep-frying foods in hot oil

**Background Science**
Deep-frying is a dry-heat cooking method. Once inside the deep-fryer, the moisture on the surface of the food begins to turn into steam, leaving tiny spaces which will be replaced by oil. As the food continues to cook, the outermost layer of starch will dry out, becoming crispy and porous. An extremely important detail of perfecting the deep-frying process, is the temperature of the frying oil. If it's not hot enough (325-375° F), the outer layer of the food will not properly dry out, and become soggy with the oil. Yet if the oil becomes too hot (more than 400° F), the food may burn instead of nicely frying. Frying takes advantage of a few delicious browing reactions, including caramelization and the Maillard reaction.

***Carmelization*****:** Interaction of sugar and heat (NOT protein breakdown – see Maillard reaction). The food is heated so much that the sugar molecules break apart to create new flavors, smells and colors.

***Maillard reaction*** **(or browning):** Extreme heat (greater than 300 degrees F) causes the amino acids inside a food to react with certain types of sugars to create new and delicious flavor compounds (dicarbonyls), which will continue to react with amino acids, causing a nice browning effect to occur on the outside of the food.

**References:**
*The Science of Good Cooking* (Cook's Illustrated Cookbooks) by the Editors of America's Test Kitchen and Guy Crosby Ph.D

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## Dippin' Dots

**Goal of Activity**: to make a deliciously cold, yet sweet treat

**Background Science:** Liquid nitrogen is -320 F, -196 C and when used in the process of making ice cream it creates a smoother dessert. Normally, making ice cream involves a lot of cranking to churn the mixture as it cools. This allows air bubbles to be mixed in so the ice cream is light and fluffy, and breaks up ice crystals as they form in the delicious mixture. The smaller the ice crystals in a dessert the smoother it is.

Liquid nitrogen as it boils, turns into nitrogen gas, which fills the ice cream with air bubbles. The temperature freezes the ingredients instantly, not giving ice crystals enough time to grow large.

**Quick Dippin' Dots Fun Facts:**

- Dippin' Dots are tiny beads of ice cream, yogurt, sherbet and flavored ice
- Microbiologist Curt Jones used his background in cryogenic technology to invent Dippin' Dots in 1988.
- Dippin' Dots are beads of cryogenically frozen ice cream. We use a combination of natural ice cream ingredients, the same found in conventional ice cream and flash freeze it using liquid nitrogen, into tiny beads.
- All Dippin' Dots for domestic customers are produced at Dippin' Dots headquarters in Paducah, Kentucky.

**Safety Concerns/Precautions:**

1. Remember to wear cryo -gloves and protective goggles when handling the liquid nitrogen
2. If pipette gets clogged, throw away and replace with a clear pipette
3. Use a plastic spoon to scoop the "beads" out of the liquid nitrogen
4. Note: This one way seem obvious but please encourage guests to practice caution with the liquid nitrogen and not to submerge their fingers or hands in the bowl.

**Procedure:**

1. Fill two sliver insulated bowls about ¼ with liquid nitrogen
2. Set up different flavors with their own bowl and 2-3 clear pipettes
3. Instruct guests to use the pipettes to make little "beads" or drops of ice cream into the liquid nitrogen
4. Scoop up the beads using a plastic spoon and serve in little medicine size plastic cup
5. While guests are participating in the activity feel free to inform them about liquid nitrogen and the process that is accruing during the forming of their Dippin' dots.

**Frankfurter or Franken-furter?**

**Goal of Activity:** This activity will show guests what "ingredients" are actually in a hot dog

**Background Science:**

In 2013 consumers spent approximately $2.5 billion on hot dogs in U.S. supermarkets. --- *National Hot Dog and Sausage Council.* Hot dogs however popular have always gotten a bad rap. Whether it's due to the idea of "mixing meats" or not exactly knowing where those particular cuts of meat come from, the science of preservatives as well as mechanically separated meats will be discussed during this activity.

***Preservatives:*** Chemical preservatives in hot dogs are used to inhibit the activity of bacteria or to kill the bacteria all together.

***Mechanically Separated Meat (MSM):*** The process entails pureeing or grinding the carcass left after the manual removal of meat from the bones and then forcing the slurry through a sieve under pressure. This puree includes bone, bone marrow, skin, nerves, blood vessels in addition to the scraps of meat remaining on the bones. The resulting product is a paste-like meat product.

**For more information: http://www.fsis.usda.gov**

**Safety Concerns/Precautions:**

People may be disgusted to find out the "ingredients" in a hot dog

**Procedure:**

1. As guests approach the activity table, they will be presented with an array of laminated ingredient cards (about 20). Guests will be asked to put together the ingredient's they think are in an original ball park hot dog.
2. After they have assembled their hot dog, volunteers will go through the ingredients list of an original Ball Park frank. Comparing guests' answers and explaining the list of ingredients to the guests.

***List of Original Ball Park Frank ingredients:*** MECHANICALLY SEPARATED TURKEY, PORK, WATER, CORN SYRUP, BEEF, CONTAINS 2% OR LESS OF: SALT, POTASSIUM LACTATE, SODIUM PHOSPHATES, FLAVORINGS, BEEF STOCK, SODIUM DIACETATE, SODIUM ERYTHORBATE, MALTODEXTRIN, SODIUM NITRITE, EXTRACTIVES OF PAPRIKA.

1. **Mechanically separated turkey**: according to the U.S. Department of Agriculture (USDA) any "Mechanically separated meat" is a paste-like and batter-like meat product produced by forcing

bones, with attached edible meat, under high pressure through a sieve or similar device to separate the bone from the edible meat tissue

2. **Pork**: Pork in terms of a hot dog include any trimmings left after the "popular cuts" have been taken. This includes:
3. **Water:** Hot dogs must be less than 10% water, according to the USDA. Water is used in the meat mixing process when making a hot dog.
4. **Corn syrup**: used to give hot dogs their added texture and sweetness
5. **Beef**: "beef trimmings" in this case, include: parts of the
6. **Salt**: a necessary mineral, hot dogs contain about 20 % of the recommended daily allotment of salt in one's diet.
7. **Potassium Lactate:** is made from neutralized lactic acid and is a common meat preservative because of its properties as antimicrobial. Making it capable of killing off harmful bacteria.
8. **Sodium Phosphate:** a general term for a variety of sodium and phosphates used as a preservative to control the pH levels in hot dogs, as well as add texture
9. **Flavorings:** Pepper, garlic, salt, and other spices according to recipe
10. **Beef stock**: Most meat stocks are usually made by boiling water with pieces of muscle, bones, joints, connective tissue and other parts of the carcass.
11. **Sodium diacetate:** A combination of sodium acetate and acetic acid, it helps to fight fungus and bacterial growth and is often used as an artificial flavor for salt and vinegar chips
12. **Sodium erythorbate:** A sodium salt of erythorbic acid, it has replaced the use of sulfites in many foods and serves as a preservative and to help keep meat-based products pink. (How does sodium erythorbate keep it pink? it increases the rate at which nitrite reduces to nitric oxide, thus facilitating a faster cure and retaining the pink coloring.)
13. **Maltodextrin:** A compound made from cooked starch (often corn in the U.S. and wheat in Europe) that is used as a filler or thickening agent in processed foods. Brewers also often use it in beer.
14. **Extractives of paprika:** An oil-based extract from the paprika plant, it can give processed food color and increase shelf life.

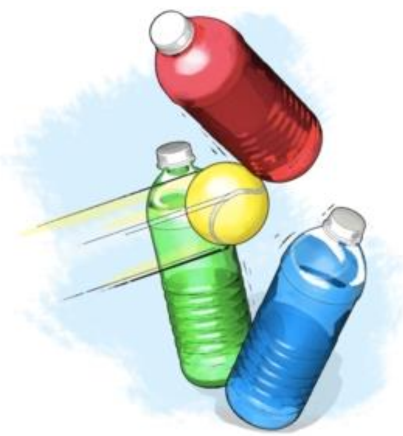
**For your information, how hot dogs are made**: Hot dogs are prepared commercially by mixing the ingredients (meats, spices, binders and fillers) in vats where rapidly moving blades grind and mix the ingredients in the same operation. This mixture is forced through tubes into casings for cooking. Most hot dogs sold in the US are "skinless" as opposed to more expensive "natural casing" hot dogs.

"Skinless" hot dogs must use a casing in the cooking process when the product is manufactured, but the casing is usually a long tube of thin cellulose that is removed between cooking and packaging. Skinless hot dogs vary in the texture of the product surface but have a softer "bite" than natural casing hot dogs. Skinless hot dogs are more uniform in shape and size than natural casing hot dogs and less expensive.

**Clean Up:** Put cards in hotdog pencil case; keep pencil cases and list of ingredients together.

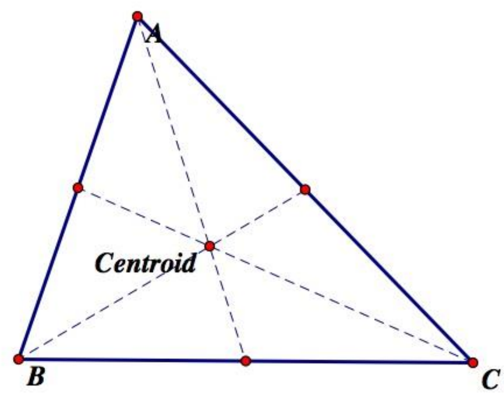
# Milk Bottle Tower – Center of Mass

**Goal of Activity:**
This activity will show visitors how the milk bottle tower carnival game operates and ways that it can be rigged.



**Background Science:**
The classic carnival game, sometimes called "One Ball", involves milk bottles stacked in a pyramid and the participant gets one throw with a ball to try and knock them all over.
A couple ways that this game can be rigged include using softer throwing devices that will affect the impact or the bottles can be weighted. To beat this game however it is important to understand the objects **Center of Mass** and how redistributing an objects mass can affect how well it balances.

An objects *Center of Mass* is the average location of most of an object's mass. If the mass is evenly distributed between the top and bottom of the object as is with a ball then the center will be in the objects center, however if the mass is not evenly distributed as with a pyramid, the center of mass will be much lower than its physical center. To find the center of mass on a three-sided figure draw a line from each corner to the center of the line on the opposite side, on a two-dimensional shape this point is called the **Centroid**




If the game is setup where the three bottles are identical in weight, shape and are in a symmetric triangle, then the center of mass is easier to estimate. If they are not and the bottom two are weighted then it can be tricky to visually estimate as the bottles will more than likely appear identical.

**Materials:**
2 stands
2 sets (6 total) evenly weighted bottles
4 bottles that are bottom heavy
Balls for tossing
Laminates for finding center of mass
Rulers
Dry erase markers and eraser

**Procedure:**

*(This procedure is operating just one setup, operate both as you see fit)*

1. Setup podium so that it is 1 foot from the wall and the table is 6 feet from podium so that guest stand in front of table to throw the balls
2. Set up 3 evenly weighted bottles in a pyramid shape on the podium
3. Have guest throw the ball once, ask where they were aiming and did it work at knocking all 3 bottles down?
4. Show guest laminates and have them find the center of mass on the pyramid graphic using the dry erase markers and rulers using the method as described in *Background Science*.
5. Have guest attempt the throw again aiming now for the spot they found using the graphics, resetting the pyramid each time
6. After around 2 attempts so that they get a feel of the throw, switch out the two bottom bottles with ones that weighted at the bottom. Have them attempt to knock it down again.
7. Allow guest to try this out as often as the line and crowd permit

**Safety Concerns/Precautions:**

- The bottles are plastic and the balls are rubber, nothing should break but be aware in case a bottle cracks
- Make sure no one is in the way during tosses

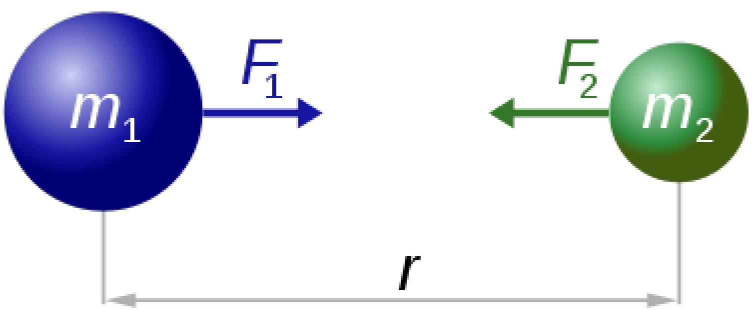
**Clean Up:**

- Put all the bottles, balls, laminates and other pieces back in box next to podiums.

**Physics of a Potato Sack Slide**

Major Concepts behind going down that slide: Gravity, Friction, Inertia, Normal Force, Kinetic Energy and Potential Energy

**Gravity** – Is the force that an object with mass exerts on objects around it. Gravity is directly proportional the mass of an object, therefore the more massive an object the greater the force of gravity pulls on the objects around it. Simple explanation = the force that pulls everything to the ground.



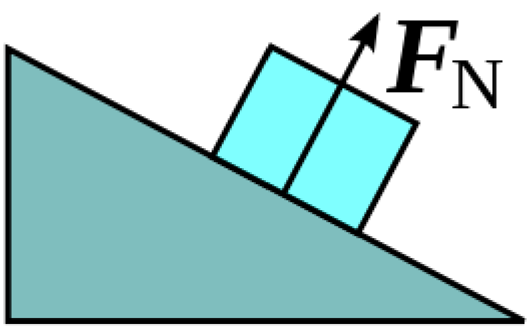

$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$$

**Friction** – Friction is a force that resists the movement of two objects past each other. As the two objects move past each their combined kinetic energy is converted to heat by Friction. Simple Explanation = **Friction** is a force that acts to stop the movement of two touching things. The energy lost to friction is turned into sound and heat. Two kinds of friction are static and kinetic. Static friction is when the friction is strong enough to stop movement between two objects. Kinetic friction is when the frictional force is not strong enough to stop all motion.( http://simple.wikipedia.org/wiki/Friction)

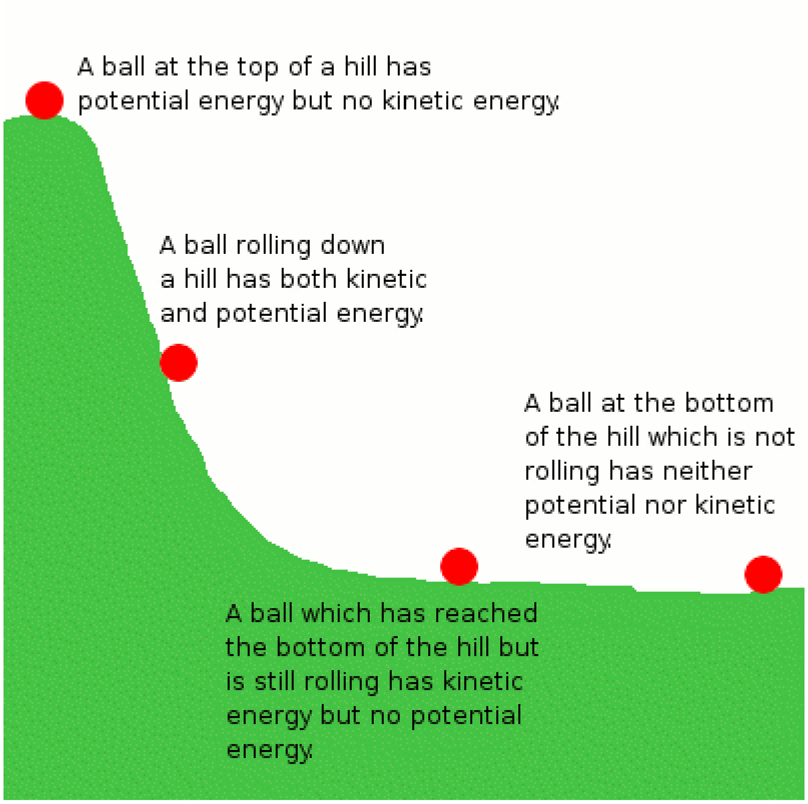
**Inertia** – The resistance of an object to any change in its motion which includes speed and direction. An object will stay still or keep moving at the same speed and in a straight line, unless it is acted upon by an outside force. (http://simple.wikipedia.org/wiki/Inertia).

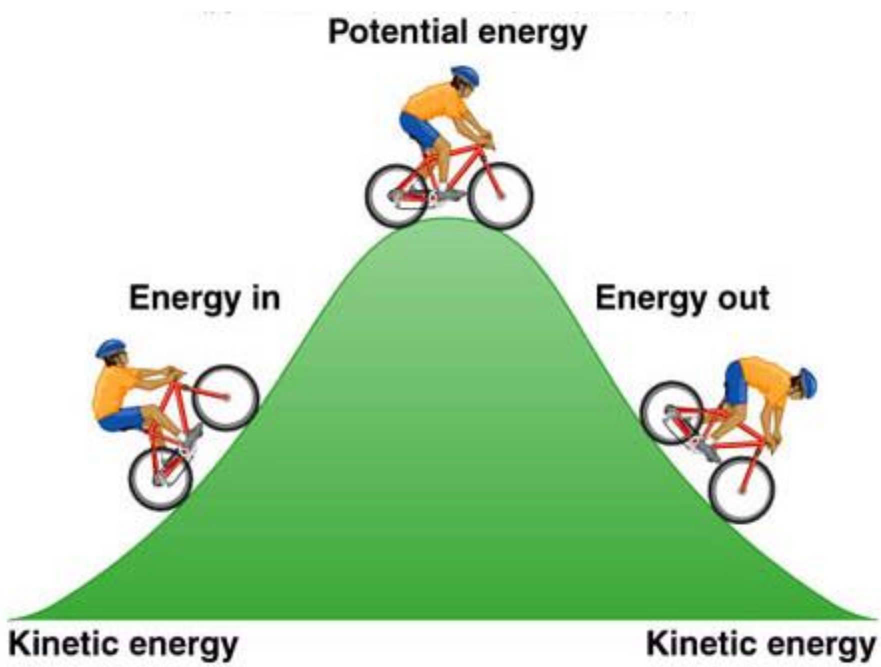
Write up continued on next page…


**Normal Force** - Normal force is the force that the ground (or any surface) pushes back up with. If there was no normal force, you'd be slowly seeping into the ground. (http://simple.wikipedia.org/wiki/Normal_force)




**Kinetic Energy** – Is the energy an object has due to the motion of that object. It is defined as the work that an object requires to move from a state of motionlessness to its current state of movement. You can think of Kinetic energy as the **energy of movement,** because it refers to any object that is moving at that present time. (http://simple.wikipedia.org/wiki/Kinetic_energy)




**Potential Energy** - In physics, **potential energy** is energy stored in a system of forcefully interacting physical entities. Potential energy is associated with forces that act on a body in a way that depends only on the body's position in space. These forces can be represented by a vector at every point in space forming what is known as a vector field of forces, or a force field.

(http://en.wikipedia.org/wiki/Potential_energy)  Simple explanation = **Potential energy** is a form of stored energy. For example, when a rock is brought up a hill and is left on the hill, the rock gains gravitational potential energy. When we stretch a rubber band, we say that the rubber band has gained elastic potential energy. Food that we eat has chemical potential energy. Batteries also have chemical potential energy. (http://simple.wikipedia.org/wiki/Potential_energy)

**Resources**

http://www.ehow.com/info_8657662_physics-playground-slide.html

http://www.unc.edu/~sjpatel/Slides.html

http://www.wired.com/2011/06/fair-physics-the-big-slide/

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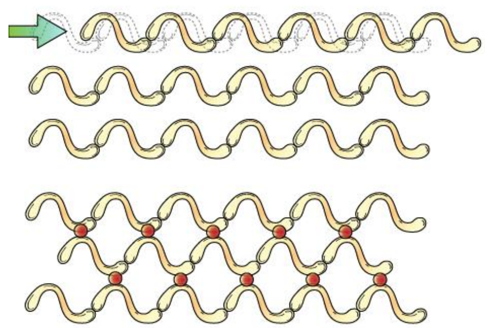
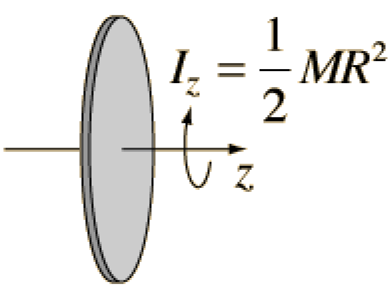
**Ring Toss – Moment of Inertia, Polymers**

**Goal of Activity:**
This activity will show visitors how the ring toss game at local carnivals is rigged and what potential strategies there are to win.

**Background Science:**
The ring toss game at carnivals is deceptively difficult. An array of bottles stand upright awaiting a ring to loop around the top of each one. The rings are typically shown to fit around the bottles by the carnival worker, and there might even be a few rings on the bottles already just to illustrate that someone before has beat the challenge. Moreover, there are so many bottles in the array, there must be a good chance to land at least one. However, the task is more challenging than it looks. Rings seemingly pop right off the bottles, even when they look like they will successfully land. The secret is in the rings.



The rings used in these games are a type of hard plastic, or ***polymer*** ("many parts"). A polymer is a long chain of ***repeating molecules***, or ***monomers*** *("one part").* Common polymers include nylon, polyvinyl chloride (PVC), silicone, and even DNA. The polymer in the rings is tightly ***cross-linked***, with molecular bridges between the long polymer chains. This makes the plastic hard and durable. This also means that these plastics will bounce more readily; they are more ***elastic***. The elasticity of the rings means that they will more readily bounce off the tops of the bottles than settle around them.




Although difficult, a technique to win this game is to stabilize the ring as it flies through the air. One way to do this is by introducing a ***spin*** to the ring. When the ring is spinning, each part of the ring wants to continue in the direction that it is already traveling (as per ***Newton's First Law of Motion***); each part of the ring has ***inertia***. When this inertia is centered around an axis of rotation, it is termed the ***moment of inertia***. The moment of inertia is measured along the axis of rotation, and ***for a disk***, is quantified by the equation:

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

Where ***m*** is the mass of the disk, ***r*** is the radius, and ***z*** is the designated axis. Given that the ring has inertia, the ring and its rotational axis resists any change in rotational position, so the ring becomes stable in flight.

The linear analogue of this is a ball that is moving in a straight line. The ball will continue to move straight so long as it is not influenced by any outside force.

**Supplies:**

- Rings
- Bottles
- Flywheel

**Procedure:**

1. Hand the visitors a few rings to throw at the bottle tops.
2. Have the visitors make a few attempts on their own; they might be successful!
3. Hand the visitors the softer, ***less elastic*** rings to try.
4. Let the visitor try introducing a ***spin*** - and thereby, a ***moment of inertia*** - to the ring to see if it flies any straighter.
    a. Demonstrate the spinning wheel with visitors.
    b. Introduce a ***spin -*** a ***moment of inertia*** - to the bike wheel and have visitors hold the handles.
    c. Encourage them to try and move the axis of the wheel
    d. Ask visitors if they feel any resistance, or ***force***, working against them.

**Safety Concerns/Precautions:**

- Be sure that visitors are throwing rings with consideration for those around them.

**Clean Up:**

- Be sure the rings are collected once each visitor is done throwing.
- Be sure that all materials are returned.

**Science of Cotton Candy**

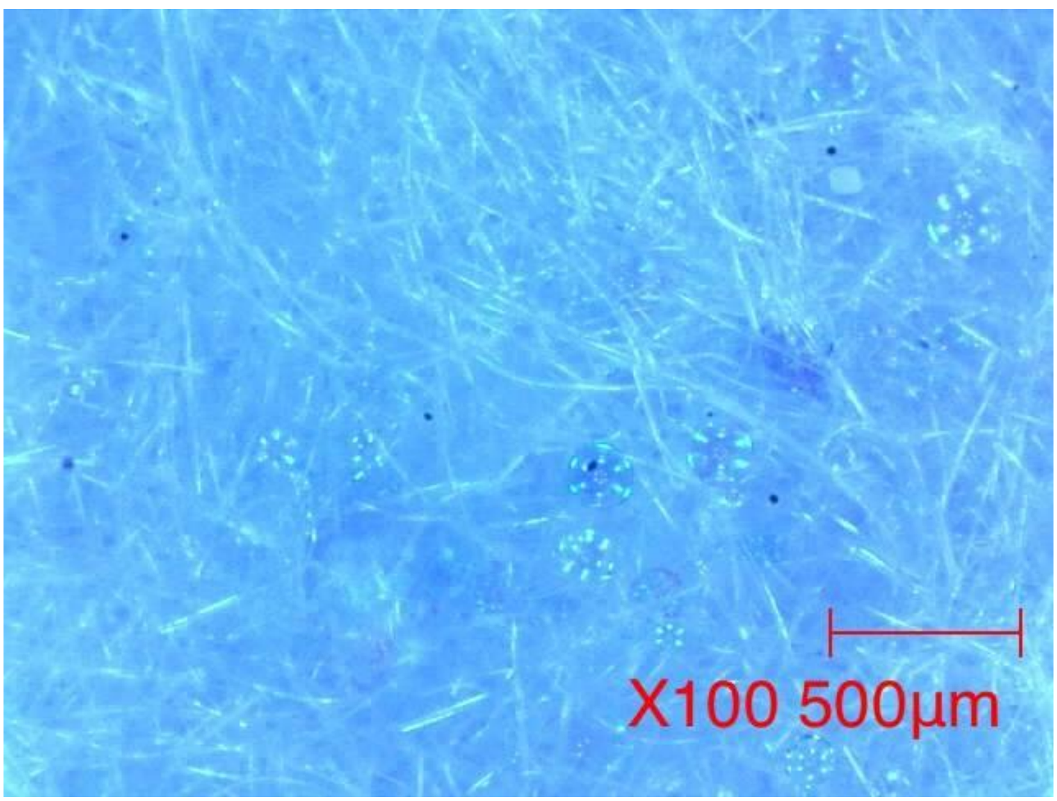
**Objective**

Understand how cotton candy takes advantage of caramelization and centrifugal forces to create delicious strands of spun sugar

**Background**

When sugar (known as sucrose) is heated to at least 374° F, it will break down into glucose and fructose, creating a sugary liquid in the process. Because this syrup is spun so quickly in a cotton candy maker, it very quickly cools down to solidify in tiny threads about 50 microns thick (about half the diameter of human hair). It does this before the sucrose has time to bond together to form crystals, allowing for these sugary strands of sucrose molecules to form.

In this demonstration, we're going to examine what cotton candy looks like at different magnifications. Below, you can see an image of what blue cotton candy looks like (with 100x magnification):



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**ProScope App Connection**

**INSTRUCTIONS**

Hello. During this presentation, we will be using a type of electronic microscope known as a ProScope. The ProScope allows you to connect to the device remotely and receive live images to your mobile device or tablet. This handout will guide you through the setup.

**Requirements**

- An iOS compatible device; iPad, iPhone, or iPod Touch.
- Free **AirMicro** app for iPhone or iPod Touch
- Free **AirMicroPad** app for iPad

***NOTE:** The AirMicro apps are not available for Android or Windows devices.

**Connecting**

1. Download and install the free **AirMicro** or **AirMicroPad** app to your iOS device.
2. On your device, navigate to the **Settings** menu.
3. Enable **Wi-Fi** on your device.
4. Connect to the **AirMicro** wireless network. The network name will be followed by three digits, (for example: AirMicro**119**).
5. Once connected, configure the **AirMicro** network by clicking on the **arrow on the right**.
6. Click on the **Static** tab, then click on the **IP Address** field and input the provided IP address: ***NOTE:** This IP address is unique to you. It can be used to connect only **one device**. If you or another visitor would like to connect with a second device, **another IP address is required.**
7. Set the **Subnet Mask** to **255.255.255.0**
8. Press the **Home Button** on your device to exit Settings.
9. Launch the **AirMicro** or **AirMicroPad** app.

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**Spin Ride Training Packet - Science After Hours: Circus**

## Learning Goals

1. Create a safe learning experience for all guests participating and viewing.
2. Allow guests to experience and come away with an understanding of motion and rotation, and how they are related.

## Opening the Spin Ride

*Unlock Spin Ride and place components (lock, red pole, yellow locking pin, and black cord) behind ride.*
The combination for the lock is 1269. Then squeeze the lock, and it will pop open.
Please keep an eye on the components so that they do not walk away. Placing them behind the ride will keep them out of sight for visitors.

## Introducing the visitor to the Spin Ride

*Ask guest if they are ok with spinning motion. Some guests may not understand what the ride does. Hold ride still while guest steps up. The guest should be seated facing you.*
Only one (1) person can be on the spin ride at a time. An adult cannot hold a child in their lap while on the spin ride.
If a young guest cannot comfortably reach the weights, they should not ride.

*Guest's feet should be under the seat and hands on top of the handles. Ask guest to slowly pull weights in.*
By pulling the weights in slowly, the guest will get an idea of how heavy the weights are without injuring themselves. Also, this serves as a control experiment to be compared to when the ride is in motion and pulling in the weights.
Remind guests to remain seated and to not kick their feet out while the ride is in motion.

## Operating the Spin Ride**

*Spin guests relatively slow. You may spin larger guests faster.*
This ride can be physically challenging to our guests. Please be sure to challenge them appropriately.

*While the ride is in motion, keep your body in front of the ride entrance and guests who are watching away from the blue pads.*
The ride in motion poses an extreme injury risk if a guest were to put a body part on the other side of the blue pads, or attempt to enter the ride. For their safety, please keep them at an arm's length away from the pads.

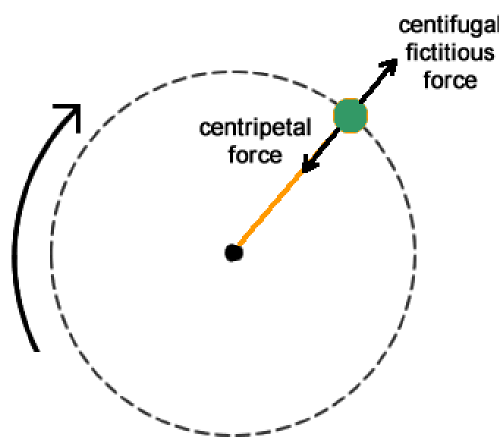
*Bring the ride to a stop, slowly.*
Carefully stop the ride as the weights pass by. Do not grab onto the weights and forcefully stop the ride. This way you do not injure yourself or the guest by stopping the ride suddenly.

*When ride is complete spin the guest the opposite direction one (1) revolution slowly.*
This will help alleviate any dizziness the guest is experiencing. Double check their eyes to be sure they are not moving quickly to one side. If you notice this occurring have the guest remain seated.

## Explaining the ride

*Ask the guest what he/she observed.*
The guest's experience should drive your conversation. Use the information provided below to help explain the phenomena.

*Why is it harder to pull the weights in while spinning?*
As the ride is spinning, the guest may feel the weights trying to move away, or a change in how heavy the weights feel. This is due to a fictitious force known as *centrifugal* force. Newton's first law of motion states an object at rest will stay at rest, and an object in motion will stay in motion, unless acted upon by another force. When you push the weights they would travel in a straight line, if not for the chains holding them to the ride. The force of the chains and rod attachments of the ride prevent the weights from traveling in a straight line. Instead, they are forced to rotate. The change in direction creates this sensation of the weights trying to move away.




The force by the rider on the weights is known as *centripetal* force. This force is directed in towards the rider, and is shared by the rider and the ride as they pull on the weights.

*Why do I spin faster when I pull in the weights?*
The rider may also notice a change in how fast they are spinning as the weights get closer. This is due to the ride's angular velocity.

Angular velocity is the rate an object rotates per amount of time. If an object is traveling in a circle, around a curve, or spinning, the orientation of the object is first determined by its distance from the center of rotation, called an axis. This distance is called a radius. The angular velocity is the result of the object's velocity in a straight line rotating a radius away from the axis. The linear velocity for the ride comes from the initial push.

As the weights are pulled closer, the radius of circle gets smaller. The ride is now traveling around a smaller circle than with the weights out. This results in a faster spin.

The law of conservation of momentum explains this phenomenon. It tells us as the weights move in the ride must speed up, and as they move out, the ride must slow down in order for momentum to be conserved.

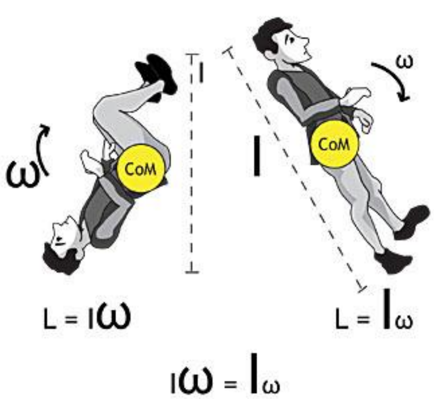
**Ending and Closing the Ride**

*Thank the guest for participating. Hold ride still while the guest gets off and remind them of the step.* Before letting them up, ask if they are feeling any dizziness.

*When your shift is done, properly lock the Spin Ride and double check that the pad lock is truly locked.* Collect the locking components from behind the spin ride. Push in weights, and rotate the ride so the plate with the hole is lined up with the hole in the floor. Insert the yellow locking bolt through the yellow platform to the hole in the floor. This will prevent the ride from rotating. Next, hook the red pole to the loop on the yellow platform, and lean it on the weight. After you attach the red pole, wrap the black cord around both weights, and insert the lock through both loops of the cord and the eye hole of the red pole. Be sure to scramble the lock so the numbers do not read 1269. Place the chain across the entrance.

## Supplemental Information - Acrobats

Ever notice how flying acrobats, and ice-skaters tuck in their arms and scrunch up their bodies while spinning in the air? By keeping their arms and legs tucked close to their centers of mass, they are able to rotate faster. This is because, just like linear momentum, the momentum of rotation, called angular momentum, is also conserved. Angular momentum depends on the speed of rotation and the distribution of weight from the center of mass.




As an acrobat flips through the air, the mass in his arms and legs is closer to his center of rotation, so his moment of inertia, i, is small, and his rotational velocity, ω, is large. To slow his rotation in the air, he extends his legs, pushing more of his mass away from his center of rotation. This makes his moment of inertia, I, larger. Because angular momentum must be conserved, his rotational velocity, ω, slows. Notice that in the tuck, and the layout, I and ω change, but their product, L, always stays the same.

The spin ride as a whole is a great example of angular momentum. Momentum is mass in motion. Linear momentum is mass moving in a straight line. It is defined as the product of mass and velocity, and is always conserved when there is no net external force acting on the object.

This does not happen in a straight line, but rather during rotation, or moving in a circle. Angular momentum, *L*, is the product of rotational inertia, *I*, and the angular velocity, ⍰. (This symbol is the lower case of the Greek letter omega.) Angular momentum is always conserved when no external torque, rotational force, acts on an object. The rotational inertia depends on the mass of the object, and how that mass is distributed.

When you first spin the ride, there is momentum. Though moving the weights changes the angular velocity, the momentum will remain the same. Faster spinning cannot occur without momentum being conserved.

<u>In order to understand the angular momentum of the spin ride</u>:

When the ride is first pushed, it has an angular momentum defined as:

$$L = I\,\omega$$

Momentum must be conserved even if the weights are moved. So:
Momentum before ($L_b$) = momentum after ($L_a$)

$$L_b = I_b\,\omega_b$$
$$L_a = I_a\,\omega_a$$

Where *I* is the rotation inertia, and $\omega$ is the angular velocity.
The rotational inertia for the spin ride is defined as:

$$I = \tfrac{1}{2}\,mr^2$$

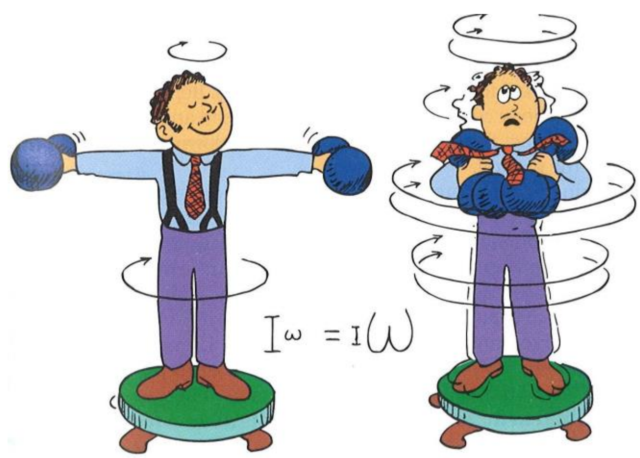
Where *m* is the mass of the weights, and *r* is the radius, or the distance one weight is from the center.

When the weights of the ride are pulled in, the rotational inertia is decreased because the mass of the weights is taking up less space. The angular velocity will be able to increase accordingly.

$$I_b\,\omega_b = I_a\,\omega_a$$

If the weights were let back out, then the rotational inertia will increase as the angular velocity decreases.

$$I_b\,\omega_b = I_a\,\omega_a$$

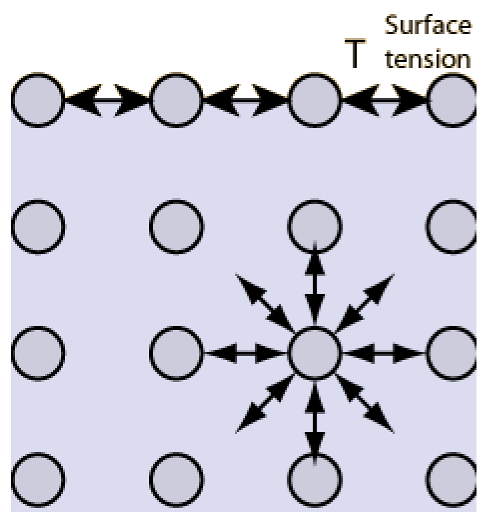


**Balloon Pop – Surface Tension**

**Goal of Activity:**
This activity will show visitors how the balloon pop at local carnivals is rigged and what potential strategies there are to win.

**Background Science:**
A fun and challenging carnival game is the balloon pop. Patrons are asked to pop a balloon or two by throwing a dart into an array. However, this game is also very challenging.

One reason that the balloons are difficult to pop is that the darts are ***dull***. The dull dart, intuitively, makes it more difficult to pop a balloon. The darts tend to bounce or deflect off the surface of the balloons before they pop.




Another reason why the game is challenging is because how the balloons are inflated. While we typically think of the surface of a balloon as being easy to rupture, this is only the case when the balloon is full. An empty balloon, in fact, is rather hard to rip. This is because a full balloon has a higher ***surface tension***. Surface tension is the ***force*** exerted by ***cohesive molecules*** as they attempt to stay together. The farther apart the molecules are pulled from one another, the stronger the force pulling them back together; this creates ***higher surface tension***.

When a balloon is completely full, the ***surface tension*** created by the cohesive rubber molecules (long ***polymer*** molecule chains) is ***high***. As an object begins to pierce the surface, the molecules surrounding the rupture will quickly snap toward the molecules to which they are still attached. This widens the rupture more and hastens the separation; the balloon pops. However, if the balloon is ***underinflated***, the ***surface tension is lower***, and therefore harder to rupture as the molecules have less of a tendency to snap away from any disturbance. This makes the balloon harder to pop. Typically, the balloons used at this carnival game are underinflated, which makes them less likely to rupture.

**Supplies:**
- Darts (sharp reds and dull blues)
- Balloons
- Board with clips
- Skewers
- Soap Solution
- Lunch tray

**Procedure:**
5. Hand the visitors a few dull darts to throw at the rigged panel with underinflated balloons.
6. Then have visitors try throwing the sharp darts at the panel with full balloons.
7. Discuss surface tension and have visitors try running a soapy skewer through a balloon.

a. Have visitors inflate a balloon ***almost fully***.
b. Give visitors a wooden skewer that has been soaking in soap solution.
c. ***Slowly*** force the skewer through the balloon ***near the tie***; this is a region of low ***surface tension***.
d. Continue by forcing the skewer out of the balloon through the ***darker end opposite the tie***.
e. The balloon should not pop if skewered properly!

**Safety Concerns/Precautions:**

- Be sure that visitors are not throwing darts when others are in the way.
- ***The darts are sharp!*** Please be careful!
- Make sure that the balloons on ***only the rigged panel are underinflated***.

**Clean Up:**

- Be sure that popped balloons are cleaned up.
- Place caps on darts prior to putting them away.
- Be sure that all materials are returned.