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iBIO STEM Kits: Centripetal force

iBIO STEM Kits welcomes you to a SCIENTIFIC JOURNEY!

Today, we will be investigating **centripetal and centrifugal forces**. The purpose of this investigation is to challenge you to investigate how we can use centripetal force (and its partner, centrifugal force) to pull on objects like coins and water. You will be making a number of devices to explore how these forces can help us to defy gravity! We also challenge you to explore this physics problem as a scientist would. What does this mean?

Scientific exploration is different than just playing around because it asks you to think about HOW you investigate. This means you need to do your investigation by observing what happens when you change a variable you have carefully chosen. This helps you to understand WHY something happens. Scientific exploration also means that you record WHAT you see or measure and that you record WHY you think it happens. The STEM Kit Journal that you are holding will help to guide your investigation and give you a place to record your observations, measurements and conclusions.

Follow the QR code at the top of the page for additional resources on this activity. This type of investigation is associated with some very exciting careers! We hope that you will explore these resources while you are doing your investigation!

Let's Get Started!

FIRST, you will need to prepare your workspace. This can be a very wet and messy investigation, so make sure that you are using a space that will not be easily damaged. A kitchen table will work nicely. To make your clean up easier, you should protect your surface by laying out some used newspaper or opening up a paper grocery bag.

SECOND, you want to lay out your materials. Use the list below to identify which materials are used in each part and organize them in your workspace. There are some additional materials that you will need to supply from your home.

Materials for Part A:

- 3 Balloons
- 1 Hex nut
- 1 Penny
- 3 Balloon clips

Other items needed:

Round objects of different sizes:
Example: penny, dime, quarter
OR
Hex nuts of different sizes

Materials for Part B:

- 1 Jello cup
- 2 Binder clips
- 2 ft of String
- 1 Clean marble
- 1 Penny (from Part A)
- 16 oz plastic cup
- Duct tape

Other items needed:

- Scissors
- Ruler
- Safety glasses

Kit Materials for Part C:

- 4 Binder clips
- 8 ft of String
- Corrugated cardboard
- 4 9-oz Plastic cups

Other items needed:

- Scissors
- A ball (optional)
- Water
- Safety glasses

LAST, you need to be prepared for experimenting safely. Parts of this experiment involve spinning objects so it is best to do this OUTSIDE and with Safety Glasses on to protect your eyes from flying objects.

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Centripetal Force-Physics

Adapted from: Steve Spangler Science- The Spinning Penny

Part A: Explore - How does centripetal force work differently on different objects?

Here's what you will need to make your centripetal spinner:

- 3 balloons
- 1 Hex nut
- 1 Penny
- 3 Balloon clips

Extension:

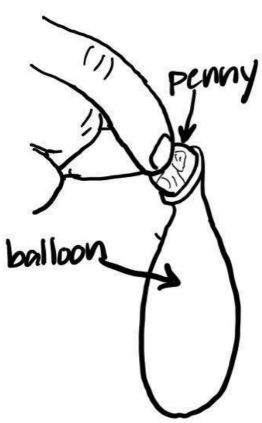
- Round objects of different sizes: Example: penny, dime, quarter
  OR
  Hex nuts of different sizes

What is centripetal force?

Have you ever spun an object like a yo-yo on its string? You can imagine what would happen if the string were to break. The yo-yo would go flying off! The yo-yo is held in circular motion by the centripetal force the string exerts on the yo-yo. Centripetal force is a force that makes an object move, or accelerate, towards the center of a circle.

In your centripetal spinner, you will have several forces at work. You will provide the energy for your objects to spin by swirling the balloon. The shape of the balloon will force the object to move in a circular path and the centripetal force will keep the penny upright so that it can continue to roll on its edge around the wall of the balloon.

If you stop swirling the balloon, the friction between the object and the balloon will eventually slow the penny down and the pull of gravity will be strong enough to pull it to the bottom of the balloon!



<u>Procedure for making a spinner:</u>

1. You will need to start with a good balloon. A standard 9 inch party balloon is a good size for this exploration. Stretch the balloon to make it easy to inflate. Blow some air into the balloon to stretch it further, then let the air out again.
2. Choose a round object that you want to start with. Let's start with the penny that came in your materials!
3. Stretch the opening to your balloon to make this next part easier. Then put your penny through the opening in the balloon so that the penny eventually goes into the larger part of the balloon. Make sure that the penny is down at the bottom of the balloon before the next step. You do not want to breathe in the penny.
4. Now inflate the balloon. If this is difficult for you, ask someone for help. Use the balloon clip to close off the balloon. You may need some help for this as well.
5. Now--the fun part! Start the spin! Hold the top of the balloon in the palm of your hand as shown in the picture. Now move the balloon in a circle with your hand until the penny begins to spin.

6. It may take a few spins to get the penny moving, but soon it will begin to spin around the wall of the balloon.
7. Stabilize the balloon. Where is the best spinning location for the penny in the balloon-- Top-Bottom-Sideways? What do you hear and why does it sound that way? How long does it take for the penny to stop spinning at the bottom of the balloon? Record your observations in the data chart.
8. Now build a second spinner, but use the hex nut as your object. How is this spinner different? Record your observations in the data chart.
9. You have an extra balloon in your kit. Make a third spinner with a circular object. Maybe a larger or smaller coin? Or a different sized hex nut? Or something completely new! Record your observations in the data chart.

Table 1: Observations of the Spinners

Object in the balloon	Where is the best spinning location in the balloon? Top? Middle? Sideways?	What sound do you hear? Why do you think it is making that sound?	Once it is spinning, start a timer. How long does it take for the object to stop spinning/moving?
Penny			
Hex Nut			

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Part B: Test - How does centrifugal force work differently on different objects?

Adapted from: Science Buddies, Centripedal Force

Here's what you will need to make ONE centripetal force generator:

- 1 Jello cup
- 2 Binder clips
- 2 ft of String
- 16 oz Solo cup
- 1 Clean marble
- 1 Penny (from Part A)
- 1 Duct tape

Other Items Needed:

- Scissors
- Ruler
- Safety glasses

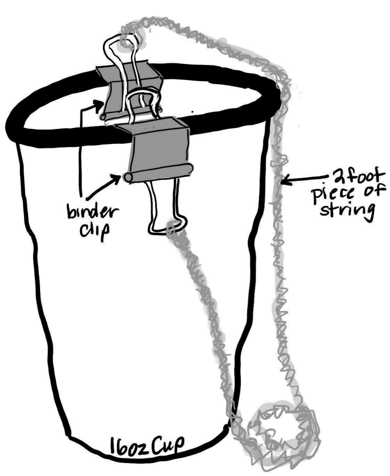
What is centrifugal force?

In our example of a yo-yo spinning in a circle by its string, it is easy to picture the centripetal force of the string pulling on the yo-yo. It is a little harder to picture in the example of the penny in the balloon because there is no string, but the centripetal force is still there. The centripetal force is pulling the penny inward to make it follow a curved path.

If we consider the yo-yo on the string further though, we realize that the yo-yo is also pulling outward on the string.

You may have experienced this force as well. Have you ever noticed during a car ride that when the car makes a turn, you feel like you are being pulled outward in the opposite direction? If you answered yes, then you have been the object that is being affected by a centripetal force- although this apparent force is often called a centrifugal force. The difference between these two forces depends on your 'frame of reference,' or the viewpoints from which you are observing something. If you are observing the yo-yo or the penny from the outside, you see an inward centripetal force pulling the object inward to keep it in a circular path. However, if you are part of the rotating system, like the person in the turning car or the penny or the yo-yo, you feel a centrifugal force pushing you away from the center of the circle.

SO...if you have centripetal forces, you also have centrifugal forces. Let's measure the effect these forces have on different objects.



Procedure for making a centripetal force generator:

1. You will need to start with the large Solo cup and the two binder clips. Clip one binder clip over the top rim of the Solo cup on one side. Clip the second binder clip to the opposite side of the rim. Take the outside metal loop on each binder clip and flip it down so that it is lying flat against the sides of the cup.
2. Cut a two foot piece of string, and then attach it to the cup by tying each end through the upright metal loops on the binder clips on the cup. Use several pieces of duct tape on either side to make sure that the clips will not move. Give it a gentle tug to make sure it is secure! This cup is your Centripetal Force Generator. Set it aside.
3. Get your Jello cup and open the foil. Place a marble on one side of the cup of Jello. Press it into the Jello so that the marble is halfway into the Jello. It should be securely in place and won't roll around. The Jello will support the weight of the marble.

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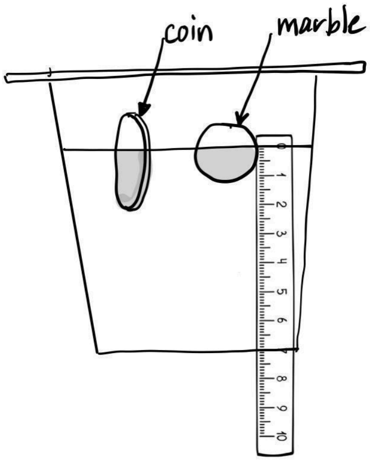
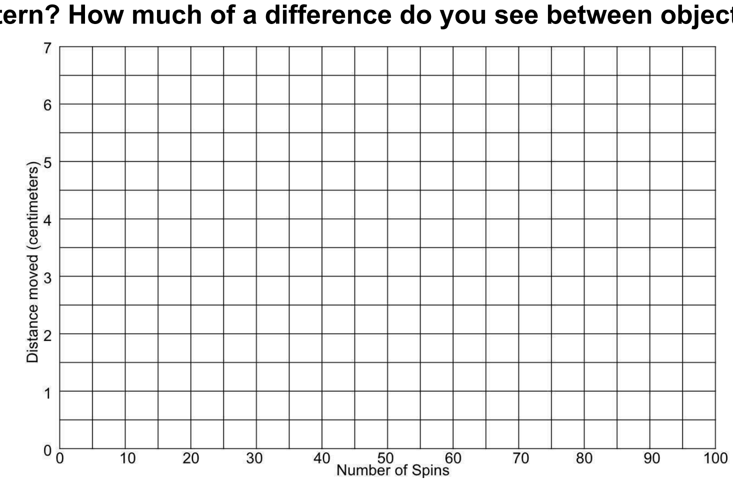


4. Insert your penny on the other side of the cup of Jello. Press it into the Jello so that the penny is sticking halfway into the Jello. It should be securely in place.
5. Place your cup with the marble, penny and Jello into the cup of your Centripetal Force Generator. If you are not already outside, go outside to an open area before moving to the next step.
6. Hold the string and spin the generator above your head hard for 10 revolutions, counting each time it goes around, then stop spinning. Remove the Jello cup and hold it up to the light to find the marble in the Jello. Use your ruler to measure (in centimeters) how deep the marble has moved. Record this movement in Table 2. Do the same measurements for the penny and record in Table 2.
7. Repeat with 10 more revolutions. Hold the Jello cup up to the light and find the marble in the Jello. Use your ruler to measure (centimeters) how deep the marble moved. Record the movement in Table 2. Do the same measurement for the penny and record in Table 2.
8. Continue repeating until the penny and marble touch the bottom of the Jello cup.

Table 2: Centrifugal Force Distance

Object	Distance (centimeters)									
	10 spins	20 spins	30 spins	40 spins	50 spins	60 spins	70 spins	80 spins	90 spins	100 spins
Marble										
Penny										

Graph: What is the pattern? How much of a difference do you see between objects?



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Part C: Test - How do you arrange objects on a centripetal force board to avoid spilling water or dropping the cups? **Adapted from:** Steve Spangler, Centripetal Force Board

Here's what you will need to make ONE centripetal force board:

- Water
- 4 Binder clips
- 8 ft of String
- Corrugated cardboard
- 4 9-oz plastic cups

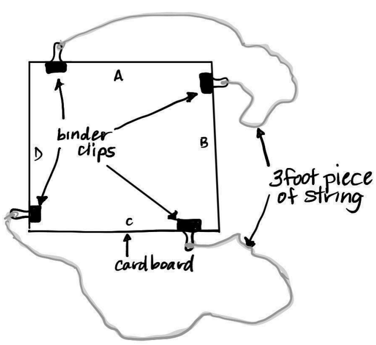
Other items needed:

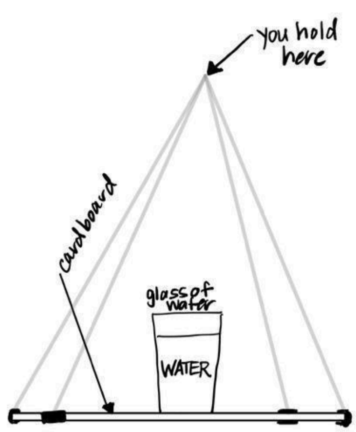
- Scissors
- A ball

Are you feeling daring?

If you were to fill your centripetal force generator with water, you might expect that as it swung around over your head, that you would experience a shower of water as gravity pulled it down. But wait! Did we cover ourselves with Jello when we swung it around? Hmmm…Can it be done?

Let's get brave and try it out! But first, we are going to build a device that will allow us to really test these forces. It is called a centripetal force board. It is simple to build and fun to test out. Let's see how much water you can swing around and remain dry!





Procedure for making a centripetal force board:

1. You will need to start with the corrugated cardboard square and the four binder clips. Clip one binder clip on the upper left of the cardboard square as shown in the diagram. Fold the metal loops so that they are flat against the cardboard on both sides.
2. Turn the cardboard. Clip the second binder clip on the upper left of the cardboard square. Fold the metal loops so that they are flat against the cardboard on both sides. Repeat this with the other two clips so that when you finish, each side of the cardboard has a metal binder clip.
3. Lay the cardboard flat on your working surface. Take the outside metal loop on each binder clip and flip it up so that it is no longer lying flat against the sides of the cardboard.
4. Cut a 3 foot piece of string, and then tie one end to the metal loop tightly on the binder clip on **side A** (see diagram). Tie the other end of the string tightly to the binder clip on **side B**. Give it a gentle tug to make sure it is secure!
5. Cut a 3 foot piece of string, and then tie one end to the metal loop tightly on the binder clip on **side C** (see diagram). Tie the other end of the string tightly to the binder clip on **side D**. Give it a gentle tug to make sure it is secure!
6. This is your centripetal force board! Make sure that both strings are exactly the same length!
7. If you are not already outside, go outside to an open area before moving to the next step. Place your board flat on a surface with the strings stretched out to the side.
8. Find your 9 oz cups. Fill each cup half-full of water. Place a cup of water in the center of the centripetal force board. (Remember centripetal force pulls objects towards the CENTER!) Draw this on your diagram on Table 3.

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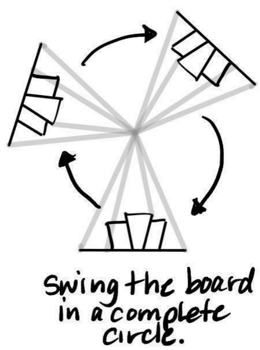

9. Pick up the strings so that they lift the board with the cup of water. Slowly begin swinging the board back and forth, making the swings get bigger and bigger and when you are ready, swing it in a complete circle. Then slowly bring the board to a stop and set it flat on the surface. Now record your observations in Table 3.
10. Now add ONE more cup of water, so that you now have TWO cups on the board. How will you arrange them so that the force is evenly pulling toward the center? Draw your cup arrangement in Table 3.
11. Pick up the strings so that they lift the board with the cups of water. Slowly begin swinging the board and when you are ready, swing it in a complete circle. Then slowly bring the board to a stop and set it flat on the surface.
12. Repeat these steps to test for THREE cups and then for FOUR cups. Don't forget to record your arrangement and your observations in Table 3!

Table 3: Centripetal Force Board Testing

	How did you arrange the cups on the board?	**Was it successful? Did you spill water? Did the cup(s) fall off? How difficult was it?**
One Cup		
Two Cups		
Three Cups		
Four Cups		

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Try an extension: Turn your Centripetal force board into a projectile throwing device

You held all of the force on the surface of the centripetal force board. What if you let it fly? This will require some practice and coordination to get to work. But you should give it a try. You will need a projectile, so you should find a ball that you can use.

1. Make a mark in the center of your centripetal force board.

2. Lay it flat on a surface with the strings stretched out to the side.

3. Place a ball on the mark. Pick up the strings so that they lift the board with the ball in the center of the board. Slowly begin swinging the board and when you are ready, swing it in a complete circle several times, picking speed and force.

4. Let go of one of the strings to propel the ball forward! How far does it go? Is it moving in the direction you planned? Can you get it to hit a target? What can you do to make it more accurate or to make it go farther? What happens if you use a ball of a different size?

5. Be an engineer and make improvements to solve these issues!