city of science

Activity Guide

Produced by World Science Festival Presented by conEdison EVERYTHING MATTERS

What is City of Science?

Produced by the World Science Festival and presented by Con Edison, City of Science is a free, traveling exhibition featuring mind-expanding demonstrations, larger-than-life exhibits, and hands-on activities designed to unleash everyone's inner scientist.

About World Science Festival

The World Science Festival gathers great minds in science and the arts to produce live and digital content that allows a broad general audience to engage with scientific discoveries. Through discussions, debates, theatrical works, interactive explorations, musical performances, intimate salons, and major outdoor experiences, the Festival takes science out of the laboratory and into the streets, parks, museums, galleries and premier performing arts venues around the world. Our mission is to cultivate a general public informed by science, inspired by its wonder, convinced of its value, and prepared to engage with its implications for the future.

City of Science Activity Guide

The City of Science Activity Guide brings the joy of discovery home. Through diverse activities, students and lifelong learners of all ages have the chance to explore general relativity, gravity, reflection, energy, and more with household objects. We encourage families to experiment together!

Next Generation Science Standards

These activities have been reviewed to correlate with the Next Generation Science Standards. The activities meet a wide range of standards from K-12 including engineering design, forces and interactions, waves, structure and properties of matter, and energy. For a complete list of standards met, please see page 26. To learn more about the Next Generation Science Standards, please visit: **www.nextgenscience.org/overview-topics**

Contact Us

Email us with questions or comments at
cityofscience@worldsciencefestival.com

Table of Contents

PENDULUM MOTION

pen·du·lum

an object hung from a fixed point so that it swings freely back and forth under the action of gravity

What You Need

- Two chairs
- Yardstick, stick, or rod
- String or yarn
- Weights, such as washers or pennies
- Tape
- Stopwatch or timer

Set Up

- Cut a piece of string 28 inches or longer.
- Tie or tape a small weight, such as a washer or a penny, to the end of the string.
- Tie the string to the middle of the yardstick.
- Place two chairs back to back with about one foot in between them.
- Hang the yardstick between the two chairs so the pendulum is hanging in the middle.

Make Your Own Pendulum

Experiment

After each test, record your observations on the next page and compare results.

TEST 1:

- Set your stopwatch for 15 seconds.
- Pull the pendulum back to a specific spot and release it.
- Count how many times it swings back and forth.

TEST 2:

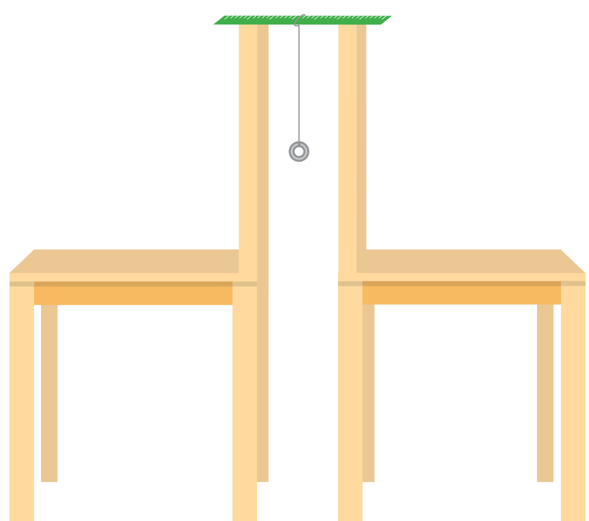
- Add weight: add additional washers or pennies.
- Repeat Test 1.

TEST 3:

- Shorten the pendulum by shortening the string.
- Repeat the test.

MORE

- Continue to experiment with different weights and lengths.
- Add more pendulums.



Record Your Observations

Number of “Periods” (or Swings)

Test	Number of “Periods” (or Swings)
TEST 1: 28” pendulum, 1 weight	
TEST 2: 28” pendulum, 2 weights	
TEST 3: 28” pendulum, 3 weights	
TEST 4: ____” pendulum, 1 weight	
TEST 5: ____” pendulum, 2 weights	
TEST 6: ____” pendulum, 3 weights	

PENDULUM MOTION

What’s Going On?

A pendulum keeps swinging because of the force of **gravity**. The only thing that changes the time it takes to make one complete swing is the length of the string—not the amount of weight, not the spot from where you release the pendulum. A pendulum eventually stops swinging because of **friction** or drag (air resistance).

Pendulum Fact

Pendulums helped scientists confirm that the Earth rotates on its axis. Foucault’s Pendulum Experiment in 1851 confirmed that the Earth rotates on its axis based on the movement of the pendulum over time. The experiment was so large it was done in the Paris Pantheon.

HUNGRY FOR MORE?

Swing Pendulum

Experiment

- Head to the park and hop on a swing. The swing is a pendulum.
- Count how many times you go back and forth when starting from different spots or at different speeds, or both.
- Race a friend. If you start at different times, do you ever sync up?

MOMENTUM

mo·men·tum

the strength or force that something has when it is moving

What You Need

- Ruler with cm marks and a groove in the middle
- Two marbles: one small, one large
- Three to four books
- Index card
- Masking or painter's tape
- Measuring tape

Set Up

- Place three books on top of each other on a flat surface.
- Lean the ruler on one end of the top book.
- Fold an index card in half and place it on its side about 15 cm from the end of the ruler on the table. Mark this spot with a piece of tape.

Marble Roll

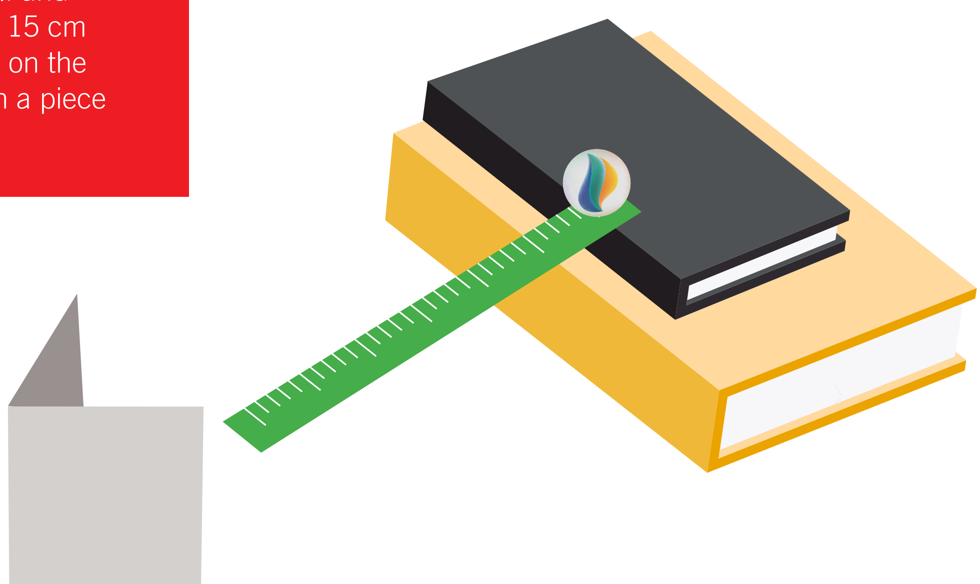
Experiment

As you perform each experiment, write down your findings on the next page.

- Place the small marble on the 4 cm mark on the ruler. Let it roll down the ruler by releasing the marble. Do not push it.
- Mark the new location of the index card with another piece of tape.
- Measure the distance in cm from the index card's starting point to its ending point.
- Repeat rolls, increasing 4 cm each time (8 cm, 12 cm, 16 cm, etc.).
- Repeat with the larger marble.

MORE

- Give the marble a little push at each different level and compare.
- Conduct this same test with toy cars on a flat board. Try experimenting with different surfaces (felt, aluminum foil, etc.).



Record Your Observations

Marble Position	Small Marble Distance (cm)	Large Marble Distance (cm)
4 cm		
8 cm		
12 cm		
16 cm		
20 cm		
24 cm		
28 cm		

MOMENTUM

What's Going On?

Before it is released, the marble has **potential** energy. As it moves down the inclined plane (the ruler), it accelerates and picks up **kinetic** energy. That energy is transferred to the card and causes it to move along the flat surface. The more you increase the height of the inclined plane, the more the marble accelerates. The more the marble accelerates, the further the card moves.

KINETIC ENERGY

ki·net·ic en·er·gy

energy associated with motion

What You Need

- Balls from your house: basketballs, tennis balls, ping-pong balls, bouncy balls, etc. (Stay away from hard balls like baseballs or golf balls that could do damage).

Galilean Cannon

Experiment

As you perform each experiment, write down your findings on the next page.

- Drop the largest ball (basketball) and note how high it bounces.
- Place a second ball (tennis ball) on top of the basketball and drop them together.
- What happens to the top ball? What happens to the bottom ball?
- Try to add a third ball to the stack and repeat.

MORE TESTS

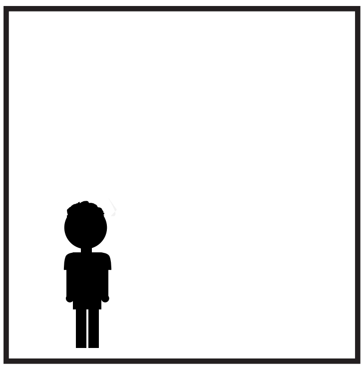
What happens when you mix up sizes? Weights? How about trying a peeled hard-boiled egg?

TIPS FOR SUCCESS

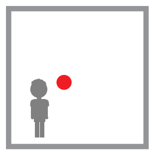
- Drop, do not bounce or toss, the balls.
- Enlist a friend to help stack the balls.
- Parents & Guardians: Create a small ring with hot glue on the basketball. Let it dry. This acts as a holder to keep the top ball in position before it is dropped.

Record Your Observations

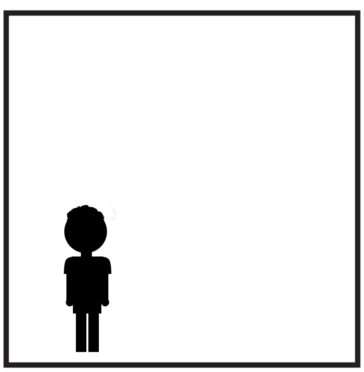
How high did the top ball go? Draw the results on the pictures below.



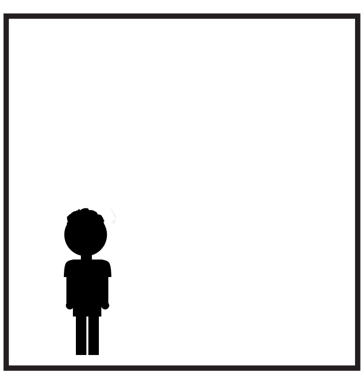
Single Ball Drop



For example, if the ball bounced as high as your head, put a mark by your head.



Two Ball Drop



Three Ball Drop

KINETIC ENERGY

What's Going On?

Individual Ball Drop

When you hold the ball in the air, all of its energy is stored as potential energy—the capability to become active. The higher you hold it, the more **potential energy** is stored in the ball. When you release it, the ball converts all of its potential energy into **kinetic energy**—energy based on motion—during its descent. Therefore, the higher you drop the ball, the faster it will hit the ground, and the higher it will bounce back.

Stacked Ball Drop

When you drop stacked balls, they free fall and separate. The bottom ball hits the ground before the one above it. After the bottom ball bounces up, it hits the top ball, transferring its upward kinetic energy to the top ball. The top ball now has extra energy and bounces higher.

Supernova Fact

A **supernova** is an exploding star. Atoms inside a star give off energy. The energy streams outward and holds the star up. Eventually, the star uses up all of its nuclear fuel, and then it collapses in on itself. Matter rushes in, rebounds like a ball bouncing off a stiff surface, sends a shockwave, ripples out layer by layer, and the star explodes.

Balloon Rocket Races

NEWTON'S THIRD LAW OF MOTION

New·ton's third law of mo·tion: for every action there is an equal and opposite reaction

What You Need

- One balloon (rocket- or round-shaped)
- One piece of string, approximately 10 feet long
- One plastic straw
- Tape

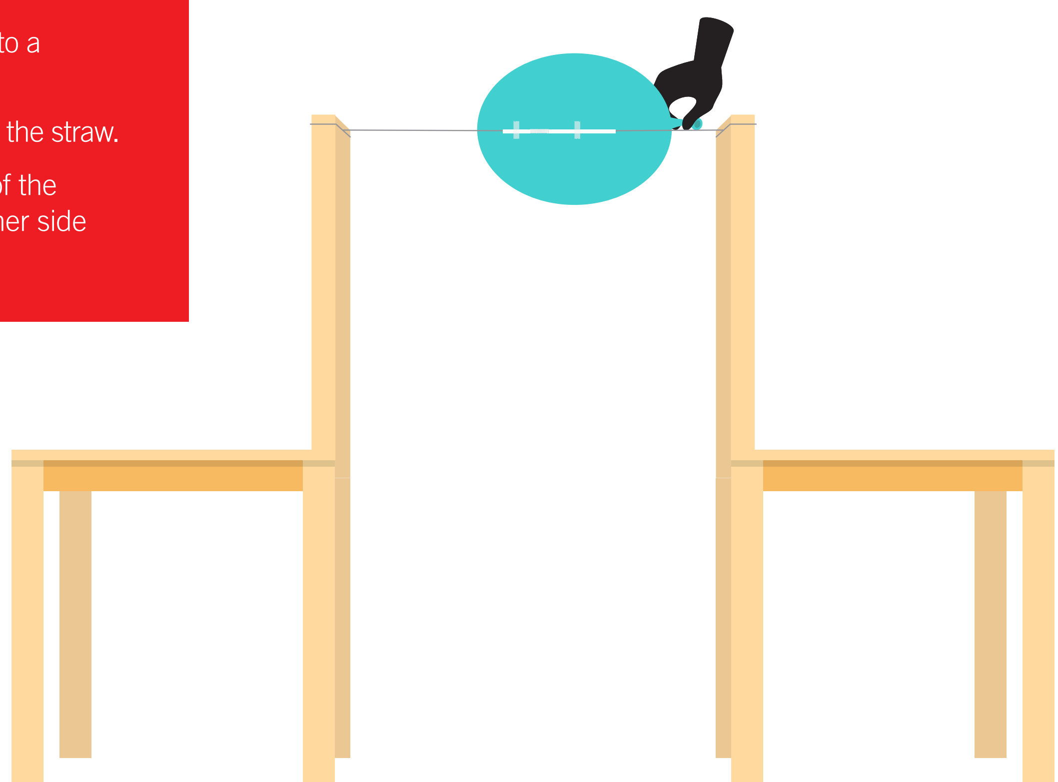
Set Up

- Tie one end of the string to a chair or doorknob.
- Thread the string through the straw.
- Tightly tie the loose end of the string to a spot on the other side of the room.

Experiment

As you perform each experiment, write down your findings on the next page.

- Blow up the balloon and hold the end. Do not tie it.
- Hold the balloon under the straw and have someone place two pieces of tape to hold the balloon onto the straw. (Don't let go yet).
- Count down: 3, 2, 1...
- Let go of the balloon.



Record Your Observations

Mark the rope below to show where your balloon ends. Mark for each experiment.

For example, mark the rope as shown below:

NEWTON'S THIRD LAW OF MOTION

What's Going On?

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. As air releases from the balloon, it pushes the balloon forward. The action is the air coming out and the reaction is the balloon moving forward.

EINSTEIN'S GENERAL THEORY OF RELATIVITY

rel·a·tiv·i·ty

a theory developed by Albert Einstein which says that the way that anything except light moves through time and space depends on the position and movement of someone who is watching

What You Need

- Plastic water bottle
- Scissors or something sharp for a parent or guardian to make holes in the bottle
- Bucket to drop bottle into (not needed if you're outside)
- Chair or ladder to stand on
- Camera with slow motion capabilities (optional)

Set Up

- Parent or guardian: make six small holes around the bottom of the water bottle.
- Fill the bottle with water and put the cap on it.
- Stand on something at least 2 feet high with the bucket below. (Children should have a parent or guardian hold them by the waist).
- Have a friend ready to film with a camera set to slow motion (optional).

Water Bottle Drop

Experiment

As you perform each experiment, write down your findings on the next page.

- While standing on your platform, take the top off the water bottle and observe the water flowing out.
- Count down: 3, 2, 1.
- Drop the bottle.
- Observe what happens to the water.
- Optional: Watch the video and see the water stop flowing out. Did you defy gravity?

Record Your Observations

Record your observations
in the box below:

EINSTEIN'S GENERAL THEORY OF RELATIVITY

What's Going On?

When the top is tightly fastened, water cannot escape from the holes due to a variety of forces, including surface tension and air pressure. When the top is loosened, air flows into the bottle, pushing on the water and causing it to flow out of the bottom holes. When the bottle is dropped, the water inside falls at the same rate as the bottle itself. The water no longer feels gravity when in free fall, so it stops spraying out. Free-falling motion appears to eliminate gravity relative to the falling bottle.

CENTRIPETAL FORCE

cen·trip·e·tal force

a force that pulls an object moving in a circular path toward the center of its path

Spinning Water

What You Need

- Sturdy square piece of cardboard, approximately one square foot
- Plastic cup or bowl
- String
- Scissors
- Water

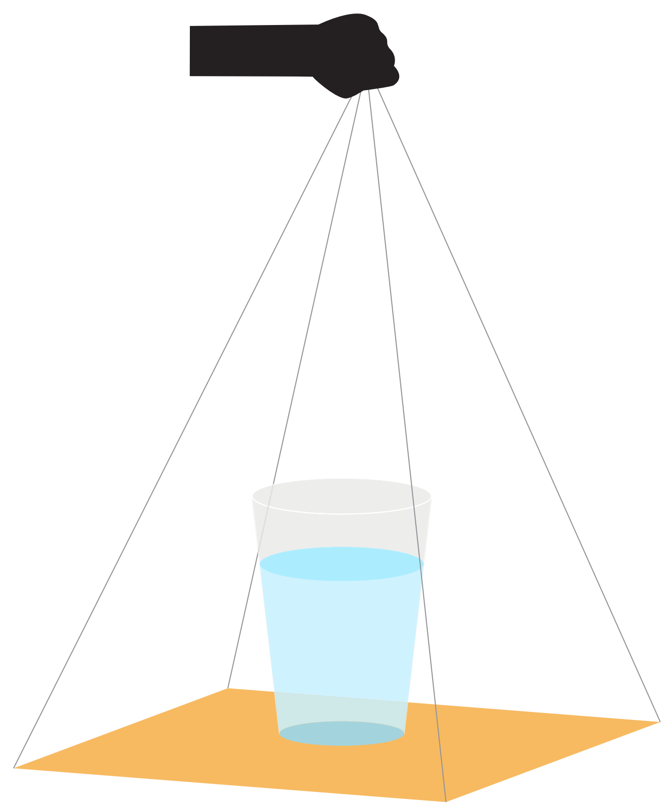
Set Up

- Parents and guardians: Use scissors to cut a square piece of cardboard and make holes in the four corners.
- Cut string into four pieces, approximately two feet long.
- Tie a knot at the bottom of each string.
- Thread one string through each hole.
- Gather strings together so the “tray” hangs evenly.
- Go outside.
- Fill half the cup or bowl with water.

Experiment

As you perform each experiment, write down your findings on the next page.

- Spin the container of water in a full circle. Go fast enough so no water spills out.
- How many times can you spin it?
- What happens when you stop at the bottom? The top?
- Try filling the container up to the top and repeat the experiment.
- Try spinning 2 or 4 cups at the same time.



Record Your Observations

Describe what you saw in the box below. Did you spill water when you filled up the container to the top?

CENTRIPETAL FORCE

What's Going On?

Newton's First Law of Motion says that an object in motion moves at a constant speed in the same direction until it's acted on by another force. We usually think of this as slowing something down, like a car going over a speed bump, but it also can mean a change in the direction of motion, like turning your car to the left or right.

Centripetal force is an example of the second part of this law. The cup and the water inside are always moving at the same speed, but when you swing it, centripetal force keeps changing its direction, moving it in a circle. When you spin the cup, it wants to fly off in a straight line, but since you have a string attached, it can only go in a circle. The cup and the water are moving together and experiencing the same forces, so neither of them falls.

OOBLECK: NON-NEWTONIAN FLUIDS

non-newtonian fluid

substance that acts like a liquid, or a solid depending on the force applied

What You Need

- Corn starch, 8 oz. or 1 cup
- Water, approximately 4 oz. or ½ cup
- Food coloring (optional)
- Large bowl

Set Up

- Pour the corn starch into the bowl.
- Add 2–3 drops of food coloring to the water (optional).
- Slowly pour the water into the corn starch, while mixing with your hand. You'll start to feel it getting difficult to mix. This corn starch mixture is called Oobleck.
- Test your mixture: You should be able to form a ball by rolling the Oobleck in your palms. When you stop rolling, it should drip between your fingers like a liquid.
  - If you can't form a ball, it's too watery. Add more corn starch, one tablespoon at a time. Mix it and test each time.
  - If it isn't runny like a liquid when picked up, it is too thick. Add more water, one tablespoon at a time.

Make Your Own Non-Newtonian Fluid

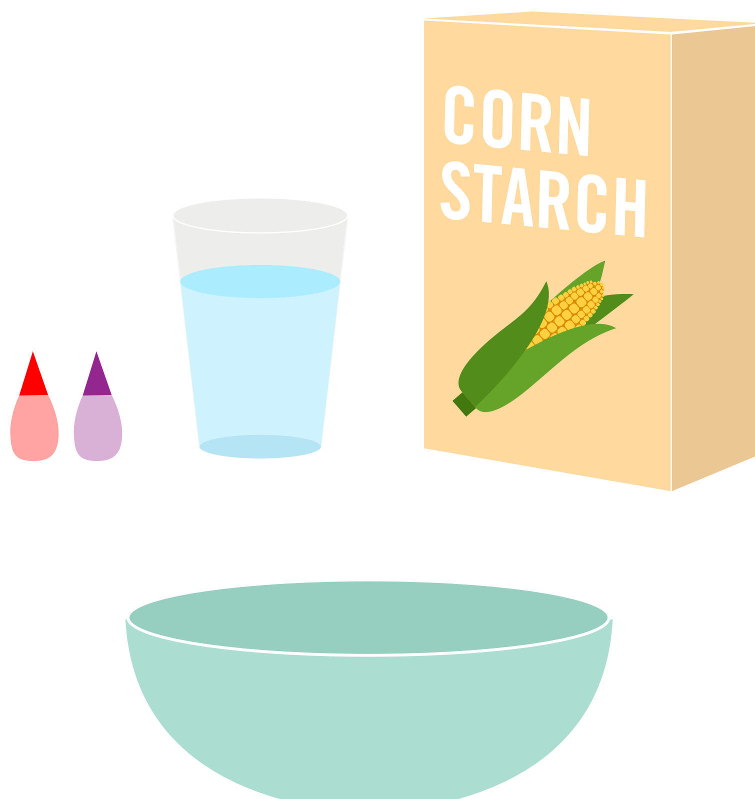
Experiment

As you perform each experiment, write down your findings on the next page.

- Drop items into the bowl of Oobleck, such as balls and pennies.
- Put pressure on the Oobleck by bouncing a ball on it or pressing down your hand.
- Record your observations.

NOTE:

Do not dispose of the mixture in the sink or toilet. It will clog. Put it in two garbage bags and throw it out.



Record Your Observations

Oobleck
(corn starch & water mix)

Weight
(Cheerio, penny, etc.)

Result

Oobleck
(cornstarch & water mix)

Weight
(Cheerio, penny, etc.)

Result

Oobleck
(cornstarch & water mix)

Weight
(Cheerio, penny, etc.)

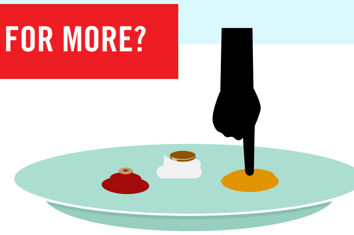
Result

OOBLECK: NON-NEWTONIAN FLUIDS

What's Going On?

Non-Newtonian fluids behave like a liquid and a solid, depending on the force exerted on them. When there is no pressure, the Oobleck acts like a liquid. But when you exert pressure, the molecules in the fluid line up and act like a solid.

HUNGRY FOR MORE?



Non-Newtonian Scavenger Hunt

Experiment

- Go on a scavenger hunt in your home to find products that are Non-Newtonian fluids. (Parents and caregivers: you can help select safe products, such as toothpaste, ketchup, and yogurt.)
- Pour one spoonful of each product on a plate.
- Test if it acts like a liquid or a solid:

  -Put a Cheerio on top of each.

  -Repeat with a penny.

  -Then press down with your fingers.

  -What happens?

SOUND WAVES

sound waves

a wave that is formed when a sound is made and that moves through the air and carries the sound to your ear

What You Need

- Box (shoe box is fine)
- Rubber bands
- Pens or pencils

Set Up

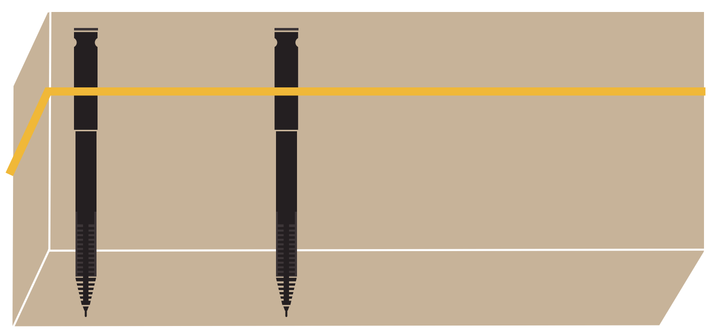
- Loop a rubber band around a box so the rubber band is tight. (It will snap when you pull and release it).
- Put two pens under the rubber band: one near the end, the other a few inches away.

Rubber Band Guitar

Experiment

As you perform each experiment, write down your findings on the next page.

- Pluck the rubber band between the pens. Note the sound.
- Move the pens farther apart and play the rubber band again.
- Keep moving the pens farther apart and playing the rubber band. How does the sound change?



Record Your Observations

Record your observations
in the box below:

SOUND WAVES

What's Going On?

The pitch depends on the frequency of the sound waves, and the frequency depends on the length of the rubber band. When the length is changed, it will vibrate at a different frequency. Shorter strings have higher frequency and, therefore, higher pitch.

BERNOULLI'S PRINCIPLE

Ber·noul·li's prin·ci·ple

a principle in hydrodynamics: the pressure in a stream of fluid is reduced as the speed of the flow is increased—developed by Swiss physicist Daniel Bernoulli in the 18th century.

What You Need

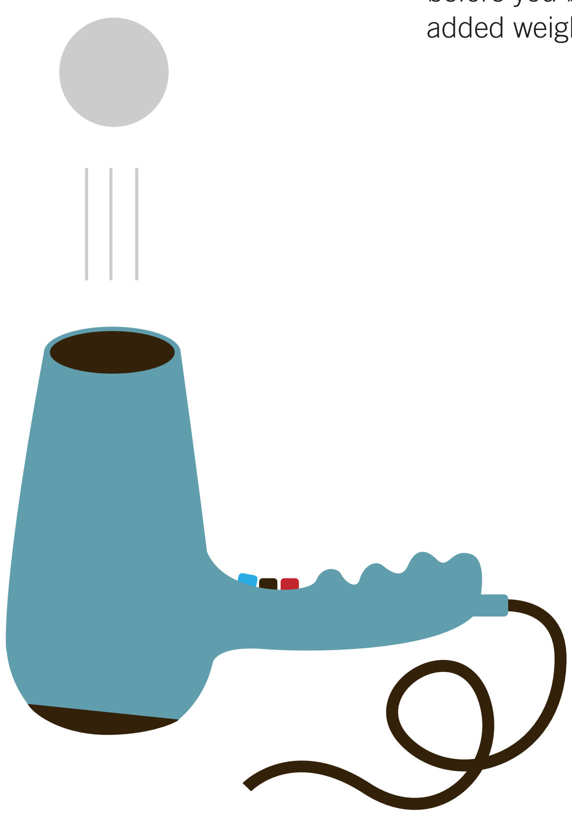
- Hair dryer
- Ping-pong ball
- Balloon and penny (optional)

Flight of the Ping-Pong Ball

Experiment

As you perform each experiment, write down your findings on the next page.

- Set the hair dryer to cool, switch it on, and point it at the ceiling.
- Carefully put the ping-pong ball in the stream of air. Hold the hair dryer steady and watch as the ping-pong ball floats in the stream of air.
- Slowly move the hair dryer from left to right and observe how the ball moves and stays in the stream of air.
- Try floating other lightweight objects in the air stream at the same time. With the hair dryer on, place an inflated balloon over your levitating ping-pong ball. You might want to place a penny in the balloon before you blow it up to give it some added weight.



Record Your Observations

Record your observations
in the box below:

BERNOULLI'S PRINCIPLE

What's Going On?

When the hair dryer is off, gravity pulls the ping-pong ball to rest on top of the nozzle. When the hair dryer is on, the air pushes the ball up. The ball floats in the air flow because of air pressure. Picture the air hitting the ping-pong ball. You can visualize that when it hits the ball, the air flows evenly to the ball's sides. The ball wants to fall because of gravity, but the pressure from the air under the ball keeps it up. The forces around the ball are even, so the ball stays in the same place, or hovers.

The air coming from the hair dryer is moving faster than the surrounding air, which means the air pressure in the column above the hair dryer is lower. When you move the hair dryer slowly, the ball is kept inside the lower-pressure column by the higher air pressure around it.

ENERGY TRANSFER

en·er·gy trans·fer

the conversion of one form of energy into another, or the movement of energy from one place to another.

What You Need

- A metal spoon that you are allowed to bend. (Ask for permission first!)

Set Up

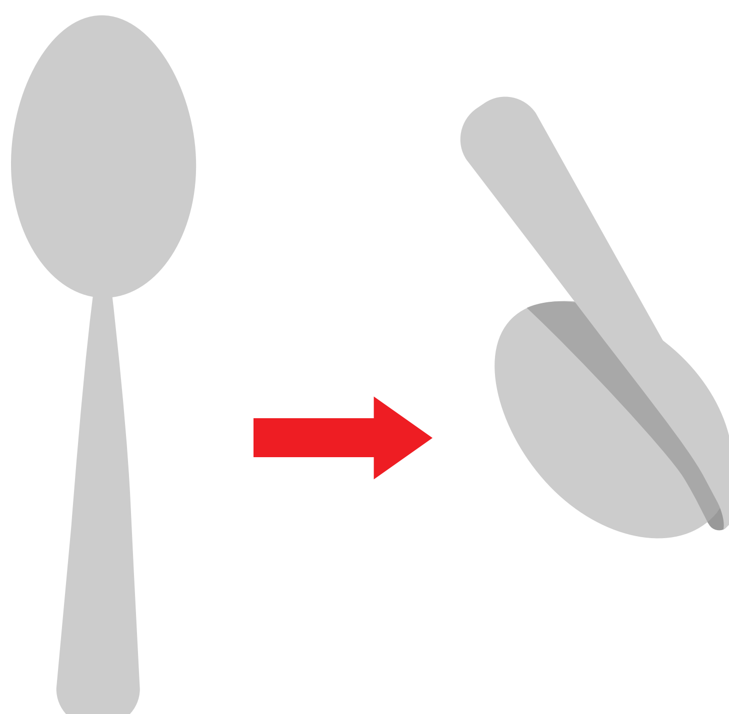
- Place the spoon bowl side up.
- Bend the handle up and over the bowl.
- Bend the handle off to one side so that it does not pass through the centerline of the bowl, but off to the edge slightly. It would be at a point about halfway between the center of the spoon and one edge of the spoon.

Rattleback*

Experiment

As you perform each experiment, write down your findings on the next page.

- Put the spoon on a table top so that it rocks back and forth nicely.
- Spin the spoon in one direction.
- Notice the direction of the rotation.
- When the spoon stops, spin it in the opposite direction.



*Experiment Courtesy of Lynn Brunelle, lynnbrunelle.com

Record Your Observations

Record your observations in the box below:

ENERGY TRANSFER

What's Going On?

The spoon rocks and rotates based on the center of gravity. The spoon may appear to be symmetrical—the same on both sides. However, since the handle is bent slightly to one side, each side is different, or asymmetrical. The masses on the opposite sides work against each other, causing the spoon to "rattle" and then rock back to spin only one way.

REFLECTION AND REFRACTION

re·flec·tion

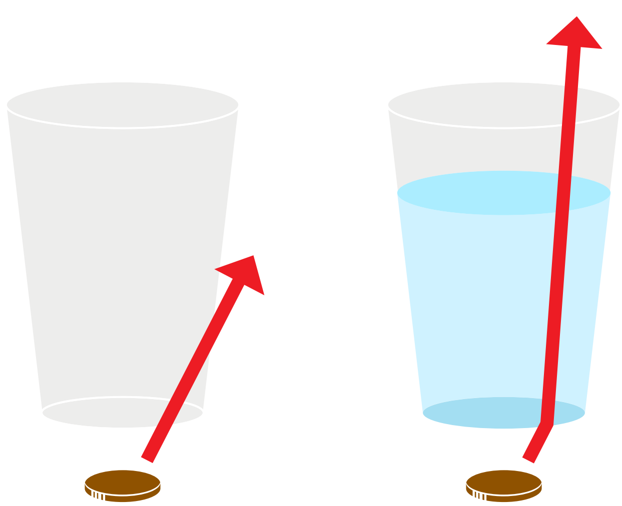
an image that is seen in a mirror or on a shiny surface

re·frac·tion

the action of distorting an image by viewing it through a medium

What You Need

- A clear (not plastic) glass. (A glass with a thin bottom, like a beaker, works best).
- Water
- Penny



Disappearing Penny

Experiment

As you perform each experiment, write down your findings on the next page.

TEST 1

- Place a dry penny under a dry glass on a dry surface.
- Look at the glass from the side, NOT the top.
- Pour the water in. Does the penny disappear?

TEST 2

- Put a penny inside an empty glass.
- Look at it from the side.
- Pour water in.
- Can you see the penny?

TEST 3

- Take a wet penny.
- Put it under the glass.
- Pour water in.
- Can you see the penny?

Record Your Observations

Record your observations in the box below:

REFLECTION AND REFRACTION

What's Going On?

Images we see are from light rays that reach our eyes. When light rays travel through the air, they do not refract or bend. That's why we can see the penny under the empty glass. When the glass has water in it, the light refracts—the light rays travel through the water and the glass—so, the rays do not reach our eyes. This causes it to appear as though the penny disappears.

Next Generation Science Standards:

Grades K-2

- K-PS2 Forces and Interactions
- 1-PS4 Waves: Light and Sound
- 2-PS1 Structure and Properties of Matter

Grades 3-5

- 3-PS2 Forces and Interactions
- 4-PS4 Waves
- 5-PS1 Structure and Properties of Matter

Middle School

- MS-PS1 Structure and Properties of Matter
- MS-PS2 Forces and Interactions
- MS-PS3 Energy
- MS-PS4-1 Mathematical representation of Waves and wave patterns

High School

- HS-PS2 Forces and Interactions
- HS-PS3 Energy
- HS-PS4-5 Technology that uses principles of wave behavior

Sources Cited:

Definitions provided by Merriam-Webster's **learnersdictionary.com**, with the following exceptions:

- Energy Transfer definition provided by **yourdictionary.com**
- Non-Newtownian Fluids definition provided by **macmillandictionary.com**

Special Thanks:

Lynn Brunelle
lynnbrunelle.com