ASME International

Engineering Magic

TRICK #6: The Egg in the Bottle Trick

Teacher's Guide

Overview of the Trick:

An empty old-fashioned quart milk bottle is sitting on the table. The Magician places a boiled egg on the bottle opening, but it is obviously too large to fit through the opening. He drapes a silk scarf over the egg. A moment later, he removes the scarf, revealing that the egg is now inside the bottle.

How the Trick Works:

(Do not reveal this to students until after they have proposed their own explanation for the trick and have completed their initial explorations.)

Prior to performing the trick, the Magician heats the bottle, causing the air pressure inside to increase. After the egg is placed in the opening, the air cools, exerting less pressure on the egg than the pressure exerted on the egg by the room air surrounding the egg. The greater pressure of the room air pushes the egg into the bottle.

Lesson Focus: **Air Pressure**

Lesson Synopsis: Students observe that after hot water is shaken around inside a 2-liter bottle and the bottle is resealed, it "collapses" as it cools. They observe that, if a small un-inflated balloon is used in place of the cap, the balloon material moves into the neck of the bottle. They infer that the Magician caused the egg to enter the bottle by heating the bottle. In **What's Going On Here?**, students are introduced to the scientific concept of **air pressure** and apply the concept in the creation of balloon rockets. As a Math Connection, students collect data and graph the relationship between the air pressure in a basketball and how high it bounces.

Related National Science Education Standards:

Content Standard B (Physical Science):

As a result of their activities in **grades 5-8**, all students should develop an understanding of **Properties and Changes in Properties of Matter.**

Fundamental concepts and principles that underlie this standard include:

A substance has characteristic properties …

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As a result of their activities in **grades K-4**, all students should develop an understanding of **Forces and Motion**.

Fundamental concepts and principles that underlie this standard include:

The position and motion of an object can be changed by pushing or pulling. The size of the change is relate to the strength of the push or pull.

Content Standard D (Earth and Space Science):

As a result of activities in **grades 5-8**, all students should develop an understanding of the **Structure of the Earth System**.

Fundamental concepts and principles that underlie this standard include:
Global patterns of atmospheric movement influence local weather.

Related Benchmarks from Benchmarks for Science Literacy:

Section 4B (The Earth):

Study of air pressure in middle school is not explicitly mentioned in the benchmarks for grades 6-8, but can help to build a bridge between the following earlier and later benchmarks:

By the end of **5th grade**, students should know that:
Air is a substance that surrounds us, takes up space, and whose movement we feel as wind.

By the end of **12th grade**, students should know that:
Solar radiation heats the … air. Transfer of heat energy … results in layers of different temperatures and densities in … the atmosphere. The action of gravitational force on regions of different densities causes them to rise or fall and such circulation … produces winds.

Section 9B (Symbolic Relationships):

By the end of 8th grade, students should know that:
Graphs can show a variety of possible relationships between two variables.

Glossary:

- **air pressure** The pressure air exerts. The pressure the atmosphere exerts on the surface of the Earth is referred to as **atmospheric pressure** and equals about 15 pounds for each square inch area at sea level. At higher elevations, there is less air pressing down, so air pressure is lower. Air pressure inside a container can be changed by adding/taking away air, by reducing/increasing the size of the container, or by heating/cooling the container.

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Important Science Concepts:

1. Air in a container pushes on the walls of the container in all directions.
2. As air in a container is heated, its pressure increases. As air in a container cools, its pressure decreases.
3. The air in a balloon is under pressure from the elastic walls of the balloon.
4. As air escapes from a balloon, the air pressure becomes lower at that end of the balloon.

Materials for Each Inquiry Team:

Materials for Initial Inquiry:

- Hot water
- Small Paper Cup
- Funnel (optional)
- 2 Empty 2-liter bottles, with caps
- Small balloons
- Rubber Bands
- Pint Canning Jar (not wide mouth)
- Tap Water
- Canning Lid and Ring

Materials for Math Connection:

- Basketball
- Air Pump with Gauge
- Measuring Tape

Materials for Building a Basic Balloon Rocket:

- Balloon
- String
- Clothespin
- Straw
- Scissors
- Tape

Materials for Additional Inquiry:

- Assorted BalloonsString
- Clothespins
- Straws
- Scissors
- Tape of various kinds

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Safety Precautions:

- Follow your laboratory safety policies in regard to whether eye protection is required. Hot tap water is adequate, but if water is heated on a hot plate or in a microwave, be sure it does not get too hot.

Procedure:

Engagement: Show the video of the **Egg in the Bottle Trick**. Have students brainstorm in their **Inquiry Journals** possible explanations for the trick.

Exploration, Explanation, and Extension: see **Student Handout**

Evaluation:

Ask students to write out an explanation of why the egg went into the bottle. (They should explain it in terms of room air pushing the egg in, not in terms of the egg being sucked into the bottle.)

Ideas for Further Exploration:

Students might consider one or more of the following questions:

1. How would the results compare if you placed the bottles/jars in ice water instead of just letting them cool to room temperature?
2. What difference would it make if you shook the bottle for less time or removed the cap longer or for less time?
3. How does the air pressure of moving air compare to that of still air? (See **Faster Air Equals Lower Air Pressure** in the **References**.)

Additional Background Information for Teachers:

The reality of air pressure is sometimes difficult for students to comprehend without experiences such as those in this lesson.

References:

- **Air Pressure**, **Physical Science Activities Manual**, available online at: http://cesme.utm.edu/resources/science/PSAM/psam25.pdf
- **Faster Air Equals Lower Air Pressure**, two experiments from the Wright Flyer Online program, available online at: http://quest.arc.nasa.gov/aero/wright/teachers/wfomanual/science/bernoulli1.html or http://quest.arc.nasa.gov/aero/wright/teachers/wfomanual/science/bernoulli2.html
- **Phantastic Physics: Airplane Wings**, available online at: http://207.10.97.102/physicszone/lesson/02forces/bernoull/wings.htm
- **Balloon Rocket Instructions**, from the **Science Museum of Minnesota**, available online at http://www.sci.mus.mn.us/sln/tf/r/rocket/rocket.html

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Student Handout

Materials for Each Inquiry Team:

- Hot water
- Small Cup
- Funnel
- 2 Empty 2-liter bottles, with caps
- Small balloons
- Rubber Bands
- Pint Canning Jar (not wide mouth)
- Canning Lid and Ring

Exploration:

1. Put half a cup of very hot (not boiling) water into an empty 2-liter drink bottle.
2. Replace the cap and shake the bottle vigorously 10 times to slosh the water around.
3. Loosen the cap and count to 5, then quickly retighten the cap in place.
4. Set the bottle on the table and observe it over a period of a few minutes.
5. Propose an explanation for what you observed.
6. Put half a cup of very hot water into a second empty 2-liter drink bottle and slosh it around as before, but this stretch the neck of a small un-inflated balloon over the neck of the bottle, using a rubber band to make sure it is securely in place.
7. Observe the bottle over a period of a few minutes.

Explanation:

Based on your observations, revise your explanation for how the trick was done.

Extension:

- Attempt to duplicate the trick, using the pint canning jar instead of a quart milk bottle, and fashioning a water balloon to take the place of the boiled egg.
- Examine the lid and ring that are used in sealing canning jars. Why is it important to heat jars of "canned tomatoes" in boiling water to promote sealing?
- See **What's Going On Here?** for the scientific explanation for your observations.

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TRICK #6: What's Going On Here?

Student Handout

Air Pressure: The Invisible Push

The **Egg in the Bottle Trick** takes advantage of the scientific principle of **air pressure**. In your inquiry, you discovered that adding hot water to a plastic bottle, sloshing it around, and recapping it somehow caused the walls of the bottle to "cave in". What you were observing was the result of the invisible push of the room air on the walls of the bottle! Sloshing the hot water around heated up the air inside the bottle, causing it to push harder on the inside walls of the bottle. When you took off the cap and counted to 5, some of this hot air escaped. Finally, when you recapped the bottle and the water cooled down, the remaining air, which had also cooled, did not push as hard on the inside walls as the surrounding air pushed on the outside walls, so the walls caved in.

Prior to performing the trick, the Magician heated the bottle, causing the air inside to push harder against the walls. Just as with the drink bottle, some air left the bottle. After the egg was placed in the opening, the air cooled, exerting less pressure on the egg (and on the walls of the bottle) than the pressure exerted by the room air. The strength of the glass walls prevented them from caving in as the drink bottle walls did. Instead, the greater pressure of the room air pushed the egg into the bottle.

What if the air pressure is higher inside than outside? That's the situation that allows you to inflate a balloon. As you force air into the balloon, the increasing pressure stretches the elastic walls and the balloon inflates until the air pressure in a balloon equals the pressure of the elastic walls plus the pressure of the outside air.

What happens when you unclamp an inflated balloon? It moves in the direction away from the opening, right? What does this have to do with air pressure? Air close to the opening is pushed out, so the air pressure against the walls close to the opening decreases. The greater pushing of the air against the walls at the opposite end causes the balloon to move in that direction. (In a rocket, burning of the fuel creates hot gases that exert extremely high pressure on the walls, allowing even a quite heavy rocket to be pushed with tremendous force.)

TRICK #6: What's Going On Here Student Handout (continued)

Math Connection:
Think about what happens when you inflate a basketball. The more air you add, the higher the pressure against the inner walls, right? Predict the relationship between air pressure and how high a basketball bounces. To find out, use a basketball and an air pump with a gauge that allows you to measure this pressure in "pounds per square inch". As you gradually increase the pressure by 1 pound per square inch, starting with an un-inflated ball, measure how high the ball bounces when dropped from a height a 4 feet. Plot your data on a graph, letting X be the pressure and Y be the height it bounced. Does your graph confirm your prediction?

Engineering Challenge:
Follow the basic instructions for building a balloon rocket, then experiment to create one that can win the classroom speed race. (**Hint:** Since the rockets are so fast, timing them to judge their performance is not going to be easy. Test your modified designs by racing 2 "models" against each other.)

Materials for Building a Basic Balloon Rocket:

- Balloon
- String
- Clothespin
- Straw
- Scissors
- Tape

Procedure:

1. Cut a long piece of string and thread it through the straw.
2. Inflate the balloon and clamp it with the clothespin.
3. Tape the balloon to the straw.
4. Attach the ends of the string to walls, chairs, etc. so that the string is straight.
5. Move the balloon to one end so that the clothespin is close to one end.
6. Release the clothespin and note the results.

TRICK #6: What's Going On Here Student Handout (continued)

Additional Materials for Inquiry:

- Assorted BalloonsString
- Clothespins
- Straws
- Scissors
- Tape of various kinds

Questions to Explore:

1. How does balloon shape affect performance?
2. How does balloon quality affect performance?
3. How does balloon size affect performance
4. How does whether or not balloon is fully inflated affect performance?
5. How does reusing the same balloon affect performance?
6. What difference does the type of string or tape make?
7. What difference does the length of the straw make?
8. What if you combine 2 or more balloons?

