Center of Gravity Toss

Physical Science Demonstration

Introduction

Observe the motion of an irregularly-shaped object as it spins around its center of mass. The path of the spinning object reveals that the net force of gravity pulls down on the object at its center of mass. The center of mass of the irregularly-shaped object follows a simple parabolic trajectory when the object is tossed into the air.

Concepts

- Center of gravity
- Newton's laws of motion
- Parabolic motion

Background

According to the laws of gravitation first proposed by Isaac Newton (1643–1727), the Earth attracts every tiny particle of mass of every object and pulls them toward the center. For any specific object (composed of many tiny particles), the *center of gravity* of the object is the location where all the individual gravitational forces acting on the individual particles add up and result in one net downward force. At this point we can assume all of the mass of the object is concentrated, and therefore this point is also referred to as the *center of mass*. The location of the center of gravity, especially for an irregularly shaped object, is critical for the overall stability and balance of an object on the Earth's surface.

In general, when a force acts on an object, it can be assumed that the force acts on the center of mass of the object. If a force is specifically applied to an object at a position other than its center of mass, i.e., to the left, right, up, or down, from the center of mass, then this force will cause the object to rotate about its center of mass. This is observed when the irregularly-shaped object is thrown and spun—it rotates about its center of mass, and the center of mass follows a smooth parabolic trajectory as it travels through the air (Figure 1).

Materials (for each demonstration)

Fishing sinker or heavy washer	Masking tape
Foam or cardboard sheet, 2′ × 2′	Pushpins, 5 (optional)
Nail	Scissors (utility knife optional)
Binder clip or clothespin	String, 50 cm
Marker	Velcro® dots, hooks (optional)

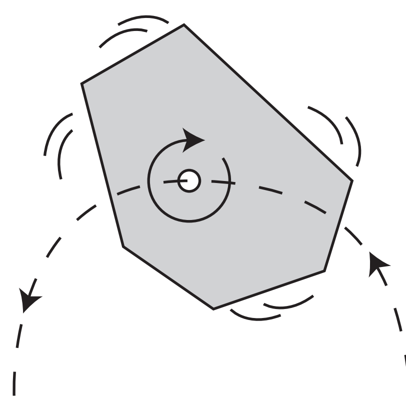

Figure 1.

Safety Precautions

The materials in this demonstration are considered safe. Use foam or cardboard that is soft and will not break or damage items in the classroom. However, do not throw the object at anyone.

Preparation

1. Obtain a thick piece of foam sheet or heavy-duty, thick cardboard. If necessary, securely tape 2–3 pieces of thick cardboard together.
2. Use a marker to draw a large (about 1′ × 1½′) irregular shape, similar to the shape in Figure 1, on the foam or cardboard.
3. Use scissors or utility knife to cut out the irregular shape. Make sure the edges of the shape are cleanly cut.
4. Cut a piece of string approximately 50 cm long.
5. Tie the fishing sinker or washer to one end of the string.
6. Tie a "looping knot" at the other end of the string (see Figure 2).

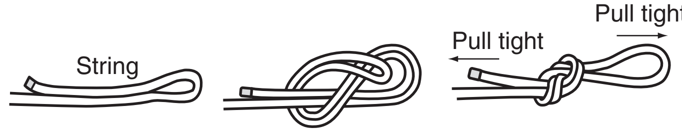

Figure 2.

Procedure

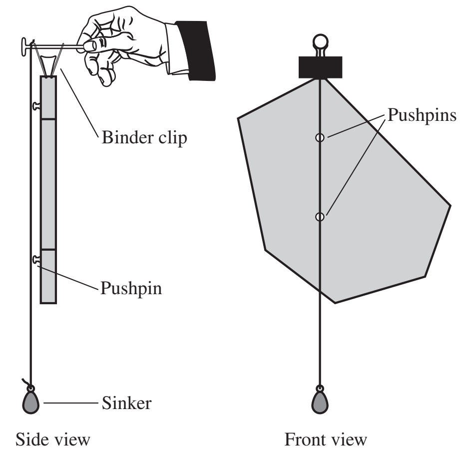

Figure 3.

1. Show the irregular shape to the students.
2. Toss the foam object forward with a backspin so the students can see the irregularly shaped object wobble as it travels along its trajectory (Figure 1).
3. Ask students if there was a point on the object that appeared to follow a stable parabolic path during its motion. Toss the object again, if necessary.
4. Attach the center of a binder clip to the very edge of one corner of the object (see Figure 3).
5. Slide the "looping knot" onto the nail and then slide the nail through the wire loops on the binder clip.
6. Hold the nail parallel to the ground and high enough to allow the foam object and string with the sinker to hang freely (Figure 3).
   Make sure the string does not get "hung up" on the object.
7. Once the object and string stop swinging and come to rest, instruct a student to place two pushpins into the foam object along the path of the vertically hanging string. If using cardboard, lightly mark the vertical path with a pen or pencil.
8. With the pushpins in place, repeat steps 4–6 at a different corner on the foam object. The student should place a third pushpin at the crossing point between the path of the vertically hanging string and the imaginary line between the two pushpins that are stuck in the foam. (This third pushpin should be the center of gravity of the foam object.) Again, if using cardboard, use a pen or pencil to mark the crossing point of the two lines.
9. As a check, repeat steps 4–6 at a third corner. The path of the string should cross the location of the third pushpin (the center of mass).
10. Remove the "center of mass" pushpin and replace it with a Velcro dot or small piece of masking tape. *Note:* Position the Velcro dot (masking tape) as close as possible to the location of the (removed) "center of mass" pushpin.
11. Remove the two remaining pushpins and the binder clip.
12. Repeat step 2 so students can observe the spinning, thrown irregularly-shaped object in motion. The dot should appear to follow a stable parabolic path.

NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School
MS-PS2 Motion and Stability: Forces and Interactions
PS2.A: Forces and Motion

Disciplinary Core Ideas: High School
HS-PS2 Motion and Stability: Forces and Interactions
PS2.A: Forces and Motion

Science and Engineering Practices
Analyzing and interpreting data
Planning and carrying out investigations

Crosscutting Concepts
Patterns
Structure and function
Stability and change

Tips

- Make sure clip is attached to as little foam as possible, and that the bottom of the clip is centered on the foam edge and remains parallel to the floor. This will help to eliminate any "extra mass" from affecting the center of mass of the foam object.
- Attach different size pinch clips or clothespins to one or two corners of the irregular object to change the location of the center of mass.

Extensions

- Place several Velcro dots on the object and then repeat step 2. See if students can determine which dot represents the center of mass by the path it follows.
- Ask students to make their own irregularly-shaped object out of cardboard or cardstock and determine its center of mass.
- Pose this question: Can the center of mass ever be located outside the physical object? Explain with an example. *Possible answers may include anything doughnut shaped such as a tire. O-ring or washer, where the center of mass would be in the center of the inner opening and not on the object itself.*

The *Center of Gravity Toss—Physical Science Demonstration Kit* is available from Flinn Scientific, Inc.

Catalog No.	Description
AP7066	Center of Gravity Toss—Physical Science Demonstration Kit

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.