Tallest Towers

Objectives

Students will learn about the center of gravity through a hands-on activity. Students will then use what they have learned to build towers using only one material, with the goal of building the tallest tower possible. Students will use the Engineering Design Process to improve their designs, build, and test to create taller towers.

STEM Focus

Physical Science: The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.

Engineering Design: Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Science and Engineering Practices: Use mathematics and computational thinking; construct explanations and design solutions; engage in argument from evidence.

Crosscutting Concepts: Cause and effect; scale, proportion, and quantity

Setup

Do the Introduction and Mini Challenge on the first day, and have students choose their material for the Main Challenge. Then, you will have a better idea of how many different materials you will need for the building day.

For Mini Challenge

- Gather empty aluminum cans and cups for each student or pair. Additionally, provide ½-cup measuring cups for each group.
- Prepare work areas that can get wet, and have towels or paper towels available.

For Main Challenge

- Gather the materials for building. Each group will choose one material (and will need quite a lot).

Suggestions

* paper cups	* paper plates	* newspaper
* cardboard	* index cards	* plastic water bottles

- Students should build their towers on the floor—not on the carpet. Spread groups around the room so that they don't knock over one another's towers.
- Take pictures or videos of the building process.

Materials

Introduction and Mini Challenge

- aluminum cans
- bottle of glue with sealed tip
- ½-cup measuring cups
- paper cups
- towels or paper towels
- water

Main Challenge

- *Tallest Towers* (page 89)
- *Reflections—Tallest Towers* (page 90)
- camera (optional)
- materials for building (See Setup.)
- measuring tapes
- paper or plastic cups
- scissors

Time Frame

The Introduction and Mini Challenge can be completed in one class session of about 40 minutes.

The Main Challenge can be completed in 45 minutes to an hour.

Follow up with the Writing Reflection as time allows.

Vocabulary

base
center of gravity
foundation
height
rotate
stable
tower
unstable

Tallest Towers

Introduction

Part 1

1. Have a few students stand with their backs against a wall so that both heels are touching the wall. Place a pencil about 1½ feet in front of them. Ask students to predict whether they will be able to lean over and pick up the pencil without moving their feet or bending their knees.

2. Have students try to pick up the pencils. Discuss what happened. Ask:

   —Why couldn't they lean forward?

   —Did they automatically put one foot out or put a hand down? Why?

   —What force is making them fall over? (*gravity*)

3. Let all students try this demonstration.

4. Tell students that one of the reasons they couldn't reach the pencil was because of their center of gravity. Ask:

   —What do you know about the term **center of gravity**? (*The center of gravity of an object is the point at which weight is evenly dispersed, and all sides are in balance.*)

✏ Write the term *center of gravity* and its definition on the board.

Part 2

1. Have students stand on one foot, holding their standing leg straight. Ask:

   —If someone gave you a little push on your shoulder, do you think you might fall over? (*yes*)

2. Have students stand on both feet, keeping their feet together and their legs straight. Ask:

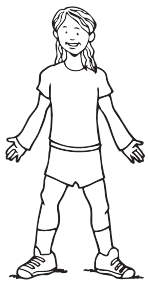
   —Does standing this way feel more **stable** (*unlikely to topple over or give way*)?

   —Would you fall if given a little push? (*maybe*)

3. Have students stand with their feet spread apart. Ask:

   —Does this position feel more stable? (*yes*)

   —If someone gave you a little push, would you fall? (*probably not*)



Explain the Science

An object becomes unstable when its center of gravity moves outside of its **base**. Tell students that their center of gravity is somewhere around their belly button in the center of their torso—the exact location is slightly different for each person. When they leaned over, their center of gravity moved away from their feet (their base) so they fell over. Normally, if they leaned over to pick up a pencil, they would either shift their weight backward, or they would put one foot out so that the center of gravity stayed in the middle, and they wouldn't fall over.

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Mini Challenge

Part 1

1. Challenge students to use what they have learned about the center of gravity in order to balance an aluminum can on its edge. (*They need to think about the center of gravity of the can and its contents.*)

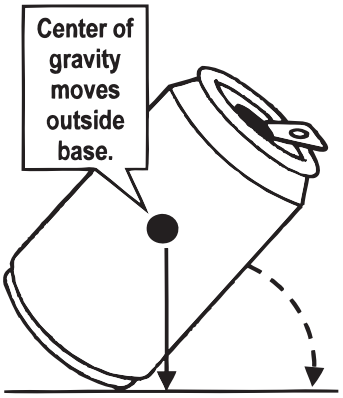
2. Give each student or pair of students an empty aluminum soda can. Let them try balancing the can for a little while.

3. Share this diagram with students. Ask:

   —Where is the center of gravity when the can is empty? (*Be sure students understand that the center of gravity is in the middle of the can, not on the outside. Ask students to explain this instead of just pointing it out.*)

   —What happens when you try to balance an empty can? (*The center of gravity moves outside of the base, and it falls over.*)

   —How could you move the center of gravity? (*Add liquid—you may have to suggest this after a time.*)



4. Give each student or pair a cup of water (no more than 8 oz.). Have them add water to the can and have them try to balance it again.

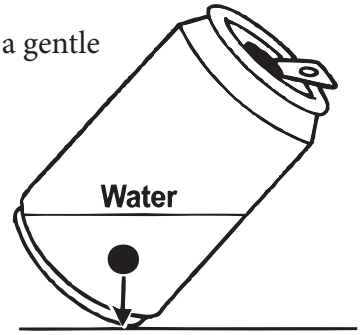
   Some students might be able to balance the can if they get the amount of water just right. The optimal amount of liquid in the can is 100 ml (just under ½ cup). Keep towels handy for any spills!

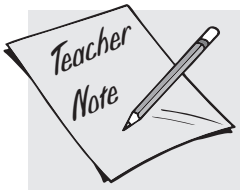
5. Show students the following diagram and tell them to try ½ cup of water in the can. If it won't quite balance, they should pour out just a little of the water until it does.

6. Once students have successfully balanced a can, challenge them to give it a gentle push to make it **rotate** (*move in a circular motion around an axis*). Ask students:

   —Where is the center of gravity in the can? (*Over the point where the can is touching the table.*)

   —How does this allow the can to move in a circle? (*The center of gravity stays over the same point as it rotates.*)





If students are having difficulty or do not believe this balancing act can be done, consider showing a short video after significant attempts have been made. Search for phrases like "balancing a soda can and rotating" or "how to balance a soda can," and, as always, preview before sharing!

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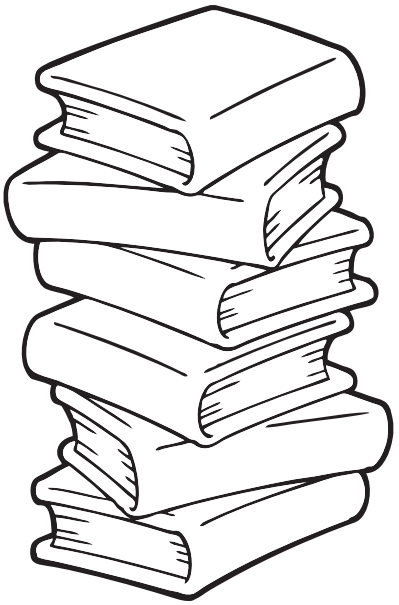
Mini Challenge *(cont.)*

Part 2



1. Remind students of their standing/balancing activity. Ask students:

   —Would you consider the balanced cans to be stable? (*No!*)

   —Why not? (*The balanced cans would definitely be classified as* ***unstable*** *since it would be very easy to knock them over.*)

2. Place a book flat down on a table and ask:

   —Is the book stable? (*Yes*)

   —How do you know? (*It would be impossible to knock the book over.*)

   —Can you point out some other objects in the room that are stable and not likely to fall over without someone making a significant effort? (*desk, chair, etc.*)

3. Point to the flat book again. Ask:

   —What if I stacked another book on top of this one? Would they be stable? (*Yes*)

   —Can I keep stacking books forever and keep them stable? (*No*) Why not? (*Because the center of gravity would keep moving up, making the tower less and less stable, and eventually, it would fall over.*)

4. As a further demonstration, try to balance a sealed bottle of glue on its tip, and then try to balance it right side up on its base. Ask:

   —Why is the bottle more stable on the flat end than on the tip? (*The tip is very small, so it's difficult for the center of gravity to stay within it. The base is wider, so the center of gravity stays within it.*)

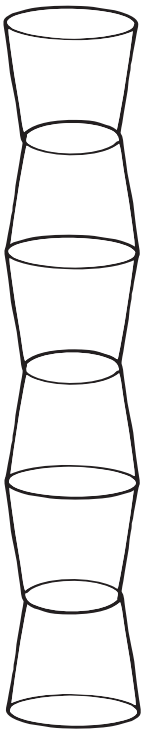
5. Have a discussion about the differences observed between things that are stable and things that are unstable. Ask:

   —What helps make things stable?

Explain the Science

Lead students to see that a larger **foundation**, or base, helps an object be more stable than a smaller foundation. An object will tip over when the center of gravity lies outside the supporting base of the object. A larger foundation gives more area for the center of gravity to stay inside. Objects that are larger or heavier toward the bottom have a lower center of gravity and are thus more difficult to tip over. Say, "Let's keep this in mind when we are building towers in the Main Challenge."

Tallest Towers



Main Challenge

Define the Problem

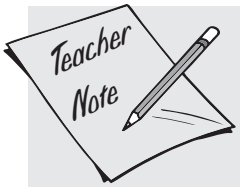
1. Tell students that, in the Main Challenge, they will build towers and will use what they have just experienced to help make their own towers stable. Ask students:
   —What is a **tower?** Discuss. (*Mention that a tower is a structure that is taller than it is wide.*)
2. As a demonstration, build a tower by stacking single cups alternately right side up and upside down on top of each other. Keep building until the tower falls. It's okay to pretend to be clumsy and stack the cups so that they fall easily. Students love outdoing the teacher!
3. Challenge students to think about how they could use what they know about the center of gravity to build a more stable tower that will be taller than yours.
4. Place students in groups of three to five. Give each group a copy of the *Tallest Towers* recording sheet and assign each group a tower-building area.
5. Go over the *Challenge Constraints* and *Criteria for Success* for this challenge.

✏ Write the constraints on the board or chart paper, and go over them with students.

Challenge Constraints

- Use only one building material.
- No tape, glue, or other connectors allowed!
- Use the chosen material any way you want. You may cut, roll, or fold it.
- Build on the floor or ground so that you can reach the top of your tower.
- If your tower falls before you can measure it, build it again.
- **Criteria for Success:** To succeed, your tower must stand on its own long enough to be measured.

6. Demonstrate how to use a measuring tape to measure **height**. Decide together if students will measure in feet and inches or meters and centimeters.
7. Remind students that they will have to be very careful while measuring so that they don't knock over their towers. Caution them to also be very careful as they move about the room so that they don't knock over another group's tower.
8. Tell students that accidental bumps are bound to happen. Be supportive, even if one member has an "oops" moment. Take student suggestions for what they could say if someone accidentally knocks down a tower, such as, *That's okay—let's build it again!* or *Oops! Let's build it again.*
9. Go over the *Engineering Design Process* (page 14) with students.



During design and testing, failure is an expected part of the engineering process. Engineers use failures to see what went wrong and to improve their designs so that, when they build the real thing, it won't fail. Let students know that they can learn from what went wrong and can try again.

Tallest Towers

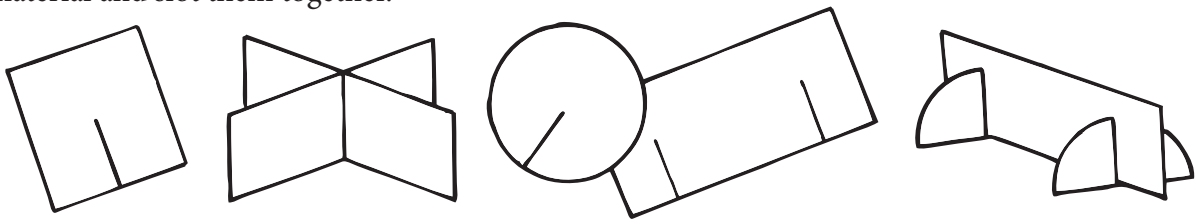
Main Challenge *(cont.)*

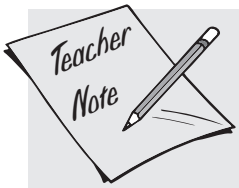
Imagine • Plan • Create

1. Show students the available materials. Give them a set amount of time to discuss how they might use each material to build a tower.

2. Encourage students to be creative and to try lots of different ways to build with just one material. Remind them that they can manipulate the material any way they want.

3. If a group is struggling, show them how to make a small cut in two pieces of cardboard or another material and slot them together.





You will be surprised at how inventive students can be when given the restriction of only using one material. Cutting slots into materials and pushing them together, rolling and folding materials into columns or beams—there are many ways to make this work! If all groups choose paper cups (it does seem to be the easiest material) you might want to do a random draw for materials or have students repeat the challenge while using a different material.

4. When time is up, have each group state which material they have selected.

5. Give groups time to discuss and sketch their first tower design.

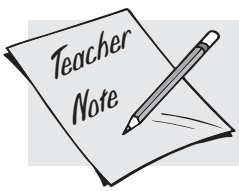
✏ Sketches should be quick and simple without too much detail.

6. Encourage students to think about what they learned in the Mini Challenge about what happens when a center of gravity gets too high up or goes off to one side.

✏ Ask students to put an ***X*** on their sketch where they think the center of gravity will be.

7. Remind students that, if they think they have a good tower, they should measure it before it falls! They can always add to it and measure again.

✏ Record all measurements on the *Tallest Towers* recording sheet.



You might have groups that build towers higher than they can reach. If possible, provide step stools or stable chairs for them to stand on and, review safety precautions.

8. Try to take photos and/or video of students working.

Tallest Towers

Main Challenge *(cont.)*

Test & Improve

1. As students are working, circulate to observe, and prompt with questions as needed. For example, you might ask:

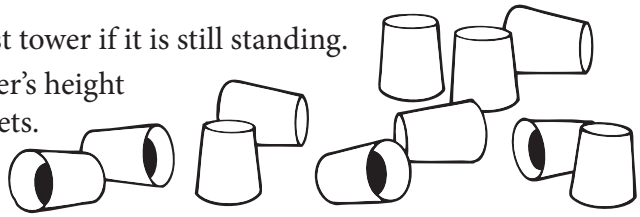
   —How did you use what you know about the center of gravity?

   —What did you change in your design after your last tower fell?

✏ Be sure that they are recording the height of each tower before they move on to a new design and that they are sketching each design before building.

2. If groups use up all of their available material in a successful tower, challenge them to try a different design. If they used a lot of their material for the foundation of their tower, suggest that, maybe, they could try a slightly smaller foundation so that they have more material for height.
3. Once students have built and measured a successful tower, encourage them to build another tower with a different design or with different materials.
4. Give students a few minutes' warning before time is up. Tell them that the tower that they are now building will be their last.
5. Once time is up, tell all groups to measure their last tower if it is still standing.

✏ Give students a couple of minutes to record the tower's height and to add other information to their recording sheets.



Analyze & Evaluate

1. Graphing will help students visualize the data to see how their towers compare to others.

✏ Have each group graph the heights of its towers. Students will need to fill in the *y*-axis with either feet/inches or meters/centimeters.

2. Have each group share their sketches and graphs and have them report on which of their towers was the tallest. Ask them to explain why they think that a particular tower design was most successful.
3. Ask each group what changes it made in its tower designs that helped make the towers taller. Encourage students to cite evidence for their answers, such as: *In our first tower, the foundation was only one foot wide. When we made it wider the tower went higher because the center of gravity stayed in the middle.*

Writing Reflection

✏ Have each student complete the *Reflections—Tallest Towers* writing reflection individually.

Extensions

- Have students select a different material and have them use it to build another tower. Each material has different properties and will present a different challenge.
- Offer some new materials, and allow one connecter. Some good combinations: straws and paper clips, toothpicks and gumdrops, uncooked spaghetti and mini-marshmallows, balloons, and tape.
- Make the challenge harder by moving the center of gravity higher. Have students build towers that hold an object at the top (golf or tennis ball, small cup with pennies or washers in it, or a textbook).

Name _____ Date _____

Tallest Towers

1. What one material did you choose to build your tower?

   _____

2. Sketch your idea for a tower in the **Tower 1** box.
3. Put an ***X*** where you think the center of gravity will be.
4. Build your tower. If it falls, build it again! Once you think your tower is ready, measure it with a measuring tape. Be careful!
5. Record the height on your sketch.
6. Once you have built a successful tower, improve your design and build and test other towers! Sketch them below.

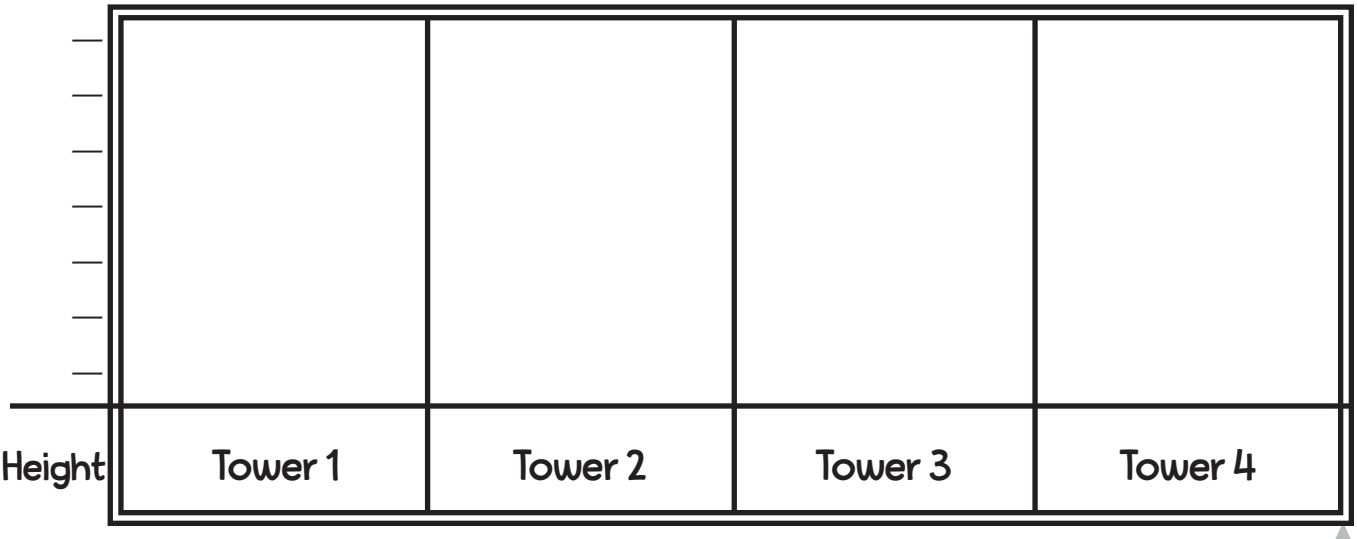
Tower 1 height: _____

Tower 2 height: _____

Tower 3 height: _____

Tower 4 height: _____

7. Graph the heights of your towers below.



Name _____ Date _____

Reflections—Tallest Towers

1. What was the challenge?

_____

_____

2. What material did your group choose? Why?

_____

_____

3. Was your first tower stable? **Yes** **No**

4. What adjustments did you make to your first tower?

_____

_____

5. In the box to the right, sketch your most successful tower.

6. How high was it?

_____

7. Why do you think that this tower was the most successful?

_____

_____

What is your evidence?

_____

_____

8. What would you do differently?

_____

_____