Ring of FIRE

Lesson Plan

GRADE 7

Brought to you by MoMATH

A Letter from the PSEG Foundation

My fascination with energy started at a young age.

The Arab oil embargo of the 1970's sent gasoline prices through the roof and made clear how closely tied our country's foreign policy is to oil interests. I began wondering whether we could produce energy in ways that didn't involve oil, and I wanted to be part of the quest to find the answer.

That passion led me to pursue years of study in the fields of physics and engineering. Graduate degrees in those areas allowed me to take on a variety of fascinating assignments in my career. I served as a research scientist at the Princeton Plasma Physics Lab, a Congressional Science Fellow in the office of U.S. Senator Bill Bradley, and a science, energy, and technology policy advisor to Governor Tom Kean before coming to PSEG where I work every day to create and deliver power responsibly.

This curriculum, developed by the Museum of Mathematics and funded by PSEG, is intended to help young people develop an interest in math and the technical fields–to spark curiosity, stimulate inquiry, and help students down a path of discovery that leads to fulfilling careers.

As issues such as climate change, energy independence, and national security demand increasingly comprehensive and technical solutions, the need for people with knowledge in science, technology, engineering, and math–areas known as the STEM subjects–will continue to grow.

At PSEG, we understand that our country's future depends on developing the insights, creativity, and dynamism of the next generation of innovators. This curriculum is one of many investments we've made in an effort to help young people discover their talents and develop a thirst for knowledge.

A math- and science-savvy workforce will lead the way to innovative technological discovery, a strengthened economy, and thriving new industries. And it is an important part of building a talent pipeline for the energy industry and our country as a whole.

Ralph Izzo
Chairman, CEO and President, PSEG

MoMath is pleased to acknowledge the support of the
Alfred P. Sloan Foundation in the creation of *Math Midway 2 Go*, and the support
of the PSEG Foundation in the creation of the accompanying curriculum.

Alfred P. Sloan Foundation

PSEG Foundation

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General Instructions for *Math Midway 2 Go*

Math Midway 2 Go (MM2GO) consists of six interactive mathematics exhibits that can travel to schools and other venues. Hands-on activities captivate and engage students, highlighting the wonder of mathematics. These exhibits were designed for use with individuals of all ages, and the mathematical topics they address range from topics in the elementary classroom to college-level mathematics. Students of all ages will benefit from open exploration of the exhibits. At the same time, the exhibits also tie into specific curricular topics for kindergarten through grade 12.

These lesson plans are provided by MoMath to support teachers like you. To help you and your students make the most of your time at *Math Midway 2 Go*, a focus exhibit has been selected for each grade from kindergarten though grade 12. The Grade 7 focus exhibit is the *Ring of Fire*.

MM2GO is designed to accommodate one class of up to 36 students at a time.

It is ideal to have only a small group of students at each exhibit while visiting *Math Midway 2 Go*. Break your class into six groups and have them rotate through the exhibits, with one group at each exhibit at a time. Before starting, make sure that students understand basic rules for interacting with the exhibits:

- Walk in the area surrounding the exhibits; don't run.
- Handle the exhibits gently.
- Do not hang or lean on the *Number Line Tightrope*.
- Handle *Ring of Fire* shapes gently.

Ideally, school support staff and/or parent volunteers will be available for the duration of the visit to *Math Midway 2 Go*. These adults can circulate throughout the exhibits, while the classroom teacher remains at the focus exhibit. At the five exhibits that are not the grade-level focus, students can explore and play.

Information about the *Ring of Fire*

About the exhibit:

The *Ring of Fire* creates a plane of laser light within its ring. Students hold translucent solids within the ring to see how the plane of light intersects the solid. In this way, students can directly and easily explore the range of possible two-dimensional cross-sections of a given three-dimensional shape. Inside a cube, for example, students can find a wide variety of cross sections including a square, various triangles, rectangles, trapezoids, and a regular hexagon. Students can manipulate each solid to find a variety of interesting cross sections.

Why visit the *Ring of Fire*?

Secondary students need to understand the relationship between three-dimensional solids and their two-dimensional cross sections (including their faces or bases). It can be quite difficult for students to visualize cross sections, but the *Ring of Fire* is designed to use eye-safe lasers and translucent shapes to do just that. This exhibit is ideal for 7th graders because cross sections are an explicit part of the 7th grade curriculum, but students of all ages will enjoy the surprising discoveries hidden inside the solids.

The *Ring of Fire* comes with five manipulatives: a cylinder, a tetrahedron, a cube, a cone, and a dodecahedron.

Integrating MM2GO Into Your Unit Plans

Consider the following key questions, class topics, and elements of the Common Core State Standards when considering how to link the *Ring of Fire* to the study of mathematics taking place in your classroom.

Key questions inspired by the *Ring of Fire*:

- How are three-dimensional figures named and described?
- What is a cross section?
- What cross sections might be found in a given solid? What is the relationship between the edges and faces of a three-dimensional solid and its cross sections?

This lesson plan will be useful with the following classes:

- Classes studying three-dimensional solids, focusing on their edges, faces, and bases
- Classes exploring cross sections for the first time

Relevant connections to the Common Core State Standards:

Learning Standards

7.G: Draw, construct, and describe geometrical figures and describe the relationships between them.
Describe the two-dimensional figures that result from slicing three- dimensional figures, as in plane sections of right rectangular prisms and right rectangular pyramids.

Standards for Mathematical Practice

- Make sense of problems and persevere in solving them.
- Model with mathematics.
- Use appropriate tools strategically.

Ring of Fire Pre-Activity

Description

In this activity, students review the names of three-dimensional solids while assembling them from their two-dimensional faces. This activity provides an opportunity for introducing the terms face, base, edge, and vertex, if students are not already familiar with these concepts.

While this activity is designed for use before visiting the *Ring of Fire*, the activity can be enjoyed independently of a visit from the Museum of Mathematics' *Math Midway 2 Go*.

Materials

- Scissors, one per pair of students (or one per student if possible)
- Tape, enough that all students have easy access to about six strips of tape
- Printed copies of shape templates—see attached. You will need at least one sheet for each student in your classroom. Ideally, these would be printed on card stock for durability, but standard paper will serve.

Key Terminology

- **Face**
- **Base**
- **Edge**
- **Vertex**
- Two-dimensional **shapes,** including **circles** and many polygons: **rectangles, squares, triangles, pentagons**
- Three-dimensional **solids,** including **cones, cylinders**, and many **polyhedra: cubes, tetrahedrons, square pyramids, rectangular pyramids, pentagonal pyramids, triangular prisms, rectangular prisms, and pentagonal prisms**

Conducting the Activity

1. Group students in pairs.
2. Give each pair a shape template. Distribute them so that there is an assortment of pages throughout the classroom. Make sure that at least one group has the shape template for each of the solids—tetrahedron, square pyramid, rectangular pyramid, pentagonal pyramid, cylinder, cube, cone, triangular prism, rectangular prism, and pentagonal prism.

Ring of Fire Pre-Activity (Continued)

3. Explain to students that when they cut out each shape on the page and assemble them together, the flat shapes will form new three-dimensional solids. All shapes will be needed to form each correct mystery three-dimensional figure.

   Each black-line master makes one three-dimensional shape when all two-dimensional shapes are used. For example, there is a sheet with two circles and a rectangle that (when assembled) makes a cylinder; when all pieces are used, this is the only three-dimensional figure that can be made. However, the sheet does not tell students that this makes a cylinder. They have to use all the pieces correctly to figure this out.

4. Tell students that they can get started cutting and assembling. Once they have used all the pieces and the final result is a complete three-dimensional figure, have them take a few minutes to describe and name the figure they have made.

5. When a pair has finished their first figure, give them a second one to try. If a group constructed the cone or cylinder in the first round, make sure you give them a polyhedron the second time. Have students repeat the steps until the figure is complete and they have discussed it.

6. While students work, you can walk around the classroom and ask students: What words can you use to describe the figure you have made? What do you know about it?

7. If you have extra copies, fast-working partners can make additional polyhedra while they wait.

8. Once all students have at least two figures in front of them, discuss the activity as a class. Start by allowing students to share their observations and descriptions of the three-dimensional solids they have made. Was it easy to figure out how to assemble them? Were there any surprising creations?

Ring of Fire Pre-Activity (Continued)

9. Discuss the shapes that have curves—the cone and the cylinder. What did they look like when they started? What two-dimensional shapes were used to make each? Explain that the remaining flat surface of a curved three-dimensional solid is called its **base**. Have students point out a base—the two circles on the cylinder and the one circle on the cone. Their curved surfaces have no specific mathematical name; they are referred to just as surfaces.

10. Next, discuss the shapes that have all flat surfaces, called **polyhedra**. Each of their flat surfaces is called a **face** and all of their faces are two-dimensional polygons. With their partners, count and name the faces on each polyhedron. Make sure students also know the names for the polyhedra they are holding.

11. Once students have identified faces, discuss the lines along which two faces meet–these are called **edges**. Have students trace an edge with their fingers until you see that all students are tracing edges.

12. Finally, identify the points where edges meet—these are called **vertices** (singular: **vertex**). Have each student place his/her finger on a vertex.

13. End the class by asking students—what did we learn today?

14. Once they have given a summary in their words, conclude that today the class took two-dimensional shapes that were sides, bases, or faces of three-dimensional solids, and constructed those solids. Then, students examined the figures to learn more. Explain that at *Math Midway 2 Go*, students will use a hands-on exhibit to determine what happens if a three-dimensional solid is sliced, using the lasers in *Ring of Fire*.

Ring of Fire Pre-Activity (Continued)

Extension One: Grouping Three-Dimensional Figures

1. Have each student pick up one three-dimensional solid. Ask him or her to find a partner in the room who has a related figure that is not the same as the one that he or she has.

2. Once each student has a partner, have each pair discuss—what is the same and what is different about their two solids? Why do the two solids go together as a related pair?

3. Then, have students re-partner. Each should find a different student with new solid related to the one that he or she has. Have students discuss—what is the same and what is different? Why do these two solids also go together as a related pair?

4. Next, ask students to make groups of three. All three students need to have different solids, but there has to be something in common among them. Have the whole group discuss—what is the same and what is different among these solids?

5. Finally—have a class discussion based on grouping. How can we group solids? What factors were students using to judge that certain solids are related?

6. Possible types of groups to discuss: solids with curved surfaces (cones and pyramids); solids that include rectangles (prisms and cylinders, even though the curved rectangular surface of a cylinder is very different from the rectangular face of a prism); pyramids; prisms; solids that include triangles; and potentially many other creative ideas from students.

Ring of Fire Pre-Activity (Continued)

Extension Two: Counting Edges, Faces, and Vertices

1. Work with students to create a four-column chart, with the four columns listing the name of a polyhedron, and the corresponding number of vertices, number of edges, and number of faces.

2. Fill in the chart with the correct data for each polyhedron.

3. Ask students: do you see a pattern? Is there a relationship between the numbers? Give students time to explore. Then, have students share their observations.

4. Next, introduce Euler's Formula, which shows that $V\text{-}E\text{+}F\text{=}2$, where V is the number of vertices, E is the number of edges, and F is the number of faces. Does this rule hold true? Have students check using the data they have generated.

Extension Three: Construct Your Own Polyhedra

1. Have students consider the flat shapes they cut out to make the polyhedra. Were they designed to fit together? How did the designer know they would fit?

2. Have students discuss what it would take to make a given polyhedron whose edges fit together. Then challenge them to do so with a polyhedron of their choice, making one either smaller or larger than the template indicated. Will the lengths of the edges change? Will the angle measures change? Have students measure, draw, cut, and create a new polyhedron from scratch.

Ring of Fire Activity

Description

In this activity, students will explore the *Ring of Fire*, using their observation skills to find cross sections in the three-dimensional solids.

Materials

- There are no specialized materials required for this activity beyond those provided with the exhibit.

Key Terminology

- **Cross section**
- **Face, base, edge,** and **vertex,** as well as proper names for two-dimensional shapes and three-dimensional solids

Conducting the Activity

1. First, allow students to examine the exhibit at their own pace. Watch students interact with the exhibit to make sure they understand that they should be picking up the three-dimensional solids, holding them inside the *Ring of Fire*, and identifying the shapes the lasers reveal. As students see and identify a given shape, they can also turn and move the three-dimensional solid within the ring, to see how that affects the laser-lit shape.

2. Once students have examined the exhibit for a few minutes, bring the group back together. Ask students what they have noticed so far.

3. Take time to discuss a particular solid, perhaps the cube, although you could equally discuss whichever solid students are most interested in. Ask students which shapes they have discovered inside the cube. Explain that these are called **cross sections**. A cross section is the shape formed when a solid object is sliced along any plane.

Ring of Fire Activity (Continued)

4. Challenge students to think about what other cross sections they might find. Tell students that back in the classroom, they will play a game to come up with exhaustive lists of the possible cross sections of a given three-dimensional solid.

5. Allow students to use their remaining time to continue exploring the *Ring of Fire*, reinforcing their use of the term cross section whenever appropriate.

Ring of Fire Post-Activity

Description

In this activity, you will replicate the experience of visiting the *Ring of Fire* exhibit with materials you may have in your classroom. If you do not have access to clay or a similar material, conduct the extension.

While these activities are designed for use after visiting *Ring of Fire*, they can be also be used with students who have not had the opportunity to experience the Museum of Mathematics' *Math Midway 2 Go*. If students have not visited *Ring of Fire*, you may need to spend some additional time introducing the term cross section.

Materials

- A malleable material, such as clay, dough, putty, etc. Ideally, each student would receive a ball the size of a typical snowball. The plans below will simply refer to this material as "clay."
- A tool for cutting clay: dental floss or piano wire work. Each student needs about 6" of the cutting material.

Key Terminology

- **Cross section**
- Students may also use the words **face, edge,** and **vertex.** These words may or may not come up in the course of the activity, but should be used accurately as students have already learned them in the pre-activity.
- Two-dimensional **shapes**, including **rectangle, square, trapezoid, parallelogram, triangle,** as well as **conic sections,** if desired: **circle, ellipse, parabola, hyperbola**
- Three-dimensional **solids**, including **cone, cylinder, cube, tetrahedron,** and **dodecahedron**

Conducting the Activity

1. Distribute one ball of clay to each student, and ask each student to form the clay into a cube.

2. Then, give each student the tool chosen for cutting the clay.

Ring of Fire Post-Activity (Continued)

3. Students should use the tool provided to cut their clay cube. The goal is to make a straight slice through the cube, creating a cross section. To avoid a jagged edge, instruct students to envision cutting into a loaf of bread or a block of cheese—the goal is a perfect, flat slice.

4. Before students cut, ask them to choose where they will cut. What shape do they expect the cross section to be?

5. After students have written down a prediction, either in words or with a sketch, they are free to cut.

6. Once they have a cross section, ask students to share with a partner. They can share where they cut, what they predicted, and what they observed.

7. Students can then mash their clay back together, make a new shape, and discover a new cross section. Depending on their interest, students can either make another cube or a different three-dimensional solid.

8. Allow students to continue exploration at their own pace. At the end of the allotted time, ask students to share what they found. You can discuss the question of whether or not the class has found all possible types of shape one can produce as a cross section of a cube. How might one be certain that the list was complete? For homework, you might have students try to draw or list all of the cross sections the class found.

Ring of Fire Post-Activity (Continued)

Materials

- An assortment of three-dimensional solids—these solids can include cubes, pyramids, cylinders, and more. They can also include common objects like cans or boxes that closely resemble the three-dimensional solids being investigated. You will need about one solid per four students. Each solid must be a different shape. Ideally, solids would be translucent, but this is not required. If you do not have access to three-dimensional solids, you can use the three-dimensional figures created in the *Ring of Fire* Pre-Activity.

- One length of string per student. String should be pre-cut into lengths of about 10” (longer pieces may be needed if the selected objects are large). Ideally, string would be colored to contrast with the solids (for example, if you have clear solids, use colored string, but if you have colored solids, use white string).

- Optional: clear tape

Extension: Cross Section Boggle

1. Count the number of three-dimensional solids you have, and split students into groups so that each group has one solid. Each group needs to have a unique solid.

2. Pass out one length of string to each student.

3. Assign each group the following task: wrap your length of string around the three-dimensional solid. This shows the cross section that would be made if you cut the solid in that place. What two-dimensional shape does it form? Students can use clear tape to keep their string in place.

4. Have the group keep a list of all the shapes they find. For a cylinder, one group might list rectangle and circle (but might not discover the ellipse).

5. After a set amount of time (three to four minutes), rotate the solids to the next group. Have students list all the shapes they find by creating cross sections of the new solid.

Ring of Fire Post-Activity (Continued)

6. Repeat until each group has examined all of the solids.

7. Then, have students trade solutions with another group.

8. Assign a point value based on the number of groups involved, with a shape found by all groups worth just one point, a shape found by all groups but one worth two points, etc. For example, if there are four groups in the classroom, and all four groups found a shape, that shape is worth one point. If three of the four groups found it, it is worth two points. If two of the four found it, it is worth three points. If only one group found it, it is worth four points. Have students help you generate the point value based on the number of groups in your classroom. The more rare a discovered shape is, the more it is worth to the team who found it.

9. Pick a three-dimensional solid to start with.

10. Have one student share a cross section. This student should demonstrate using his or her string and the solid; make sure all the students understand, focusing on the groups who did not generate that shape themselves earlier.

11. Count how many groups generated that cross section and grade accordingly. For example, if five of seven groups found the rectangular cross section of a cylinder, each of those five groups gets three points.

12. Continue through all the cross sections the class has found. Which group earned the most points? Have a wrap-up discussion about any surprising cross sections that students discovered.

Ring of Fire Post-Activity (Continued)

Materials

- A physical cube for each student, which could be a paper model made earlier, a wooden block, or even a large number cube
- Some means of non-destructively marking the cube
- Computer for each student (this activity can also be done in groups if needed)

Extension: Computer Cross Sections

1. Explain to students that today they will be using a computer applet to check the cross sections they envision in a solid cube, just the way they used a laser to look for cross sections inside translucent three-dimensional solids with the *Ring of Fire*.

2. Give each student a cube and ask him or her to mark two dots along every edge, which divide that edge into three equal segments, and also to put a mark at each vertex of the cube.

3. Select a possible shape from the list of cross sections of a cube on the applet at http://www.mhhe.com/math/ltbmath/applets/ch9/index.html as a challenge for your students, such as a non-square rectangle, or a trapezoid.

4. Ask students to try to choose some of the marked points on their cube which will form the corners of the goal shape, so that if you sliced the solid cube along the plane determined by those points, the cross section would be that desired shape. Students should highlight their selected points, perhaps with post-it flags, or by circling them. Then have students look at the cube from various angles to see if their selected points really do form the goal shape. If the shape doesn't seem to match, students should try to adjust their selection until it looks like a match.

5. To check their solutions, set up each student with an individual computer and direct him or her to that applet:
http://www.mhhe.com/math/ltbmath/applets/ch9/index.html

Ring of Fire Post-Activity (Continued)

6. Tell students to select the goal shape from the pull-down list on the left, and then click on three of the points they selected as corners of the goal shape. (Note that if you are working with a goal shape that is not a triangle, the applet will not allow students to click on all of the corners of the shape.) When they have selected three points that correspond to ones they chose on the physical cube, they can click on the "Create" button to reveal the cross section created by slicing through those three points.

7. If the cross section generated does not match the goal shape, students can click on "Reset" to adjust their selection and try again.

8. Once two students sitting near each other have found the goal shape, ask them to share their solutions. Did they click on the exact same three points? What do the solutions have in common? By clicking on the "Rotate Cube" button and dragging the image, have students manipulate the image so they goal shape is viewed straight on, parallel to the plane of the screen. The students can then orient their physical cube to match and look at the highlighted points to help visualize the cross section in the real world.

9. Allow time at the end of class to share. If you have a projector, hook it up to one computer and allow students to share solutions until the entire class has seen all of the challenge cross sections: scalene triangle, isosceles triangle, equilateral triangle, square, non-square rectangle, isosceles trapezoid, trapezoid, parallelogram, non-regular pentagon, and non-regular hexagon.

Shape Templates

Cut out instructions and hand one to each group as needed.

1. Cut along heavy lines.
2. Crease tabs along thin black lines.
3. Figure out how the shapes are designed to fit together. Use the dashed lines to see where tabs should go.

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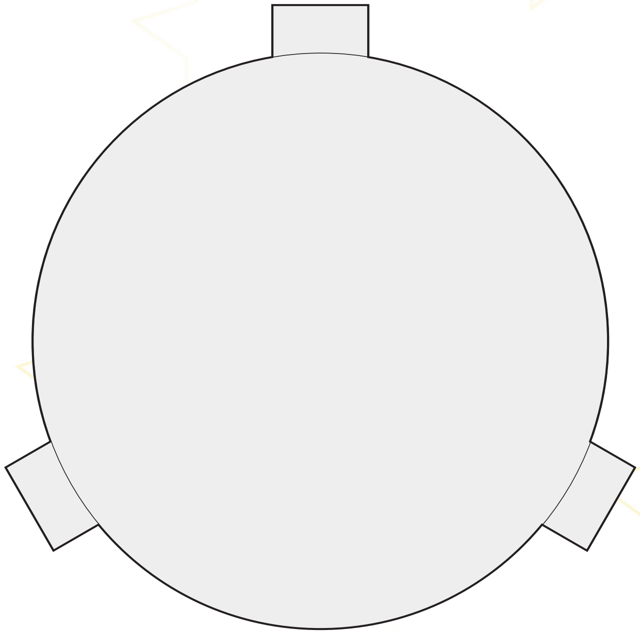

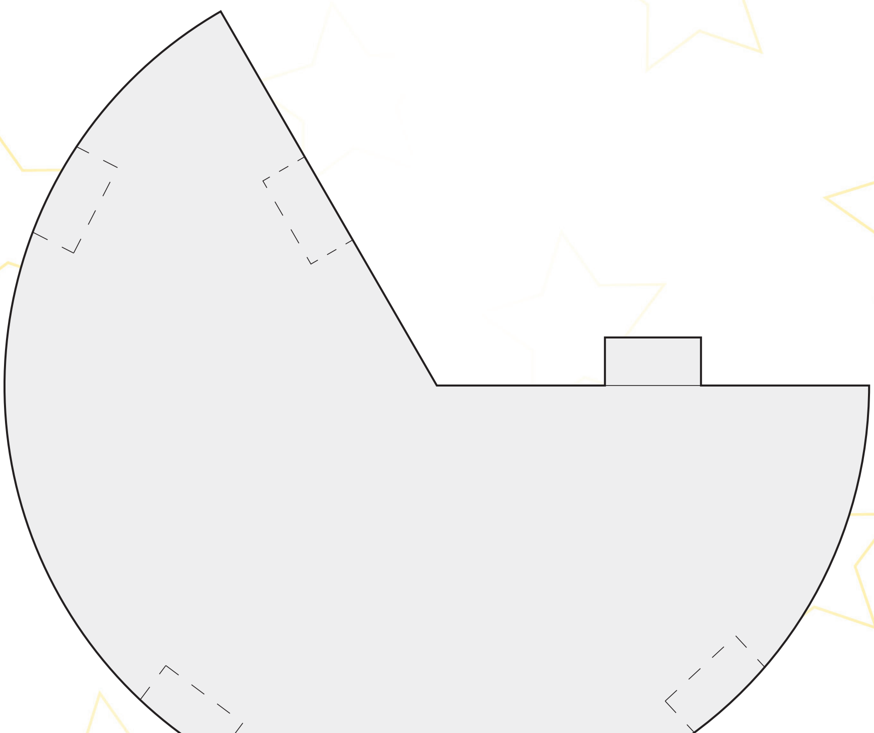

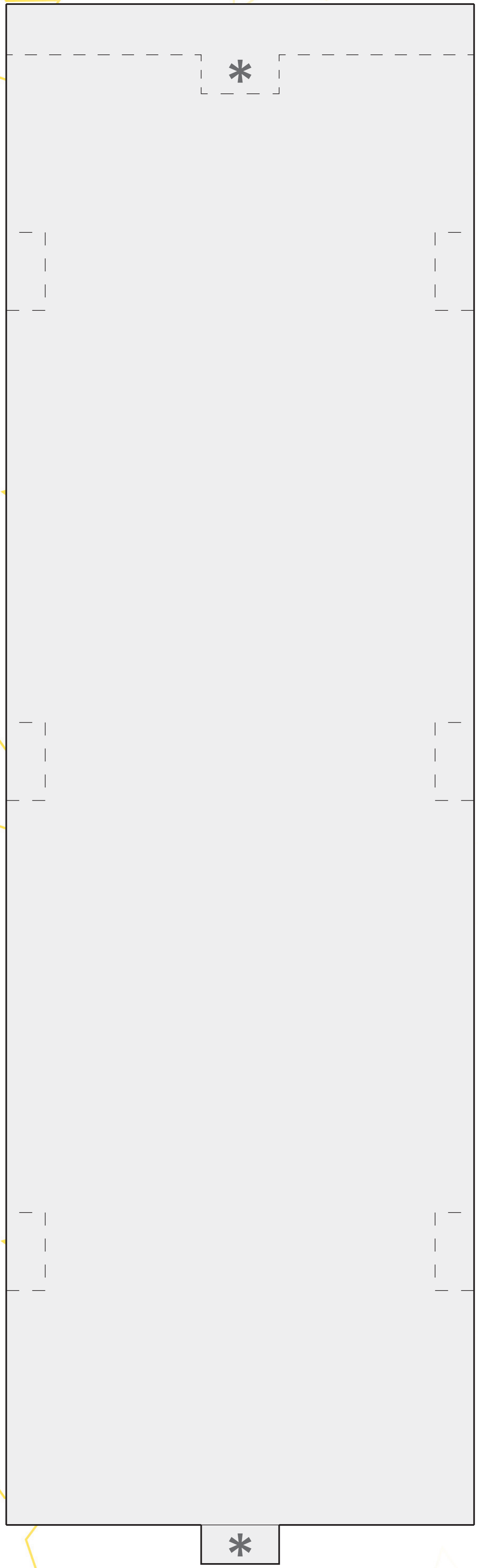

This shape overlaps with itself.
When you put it together,
make sure that one *
ends up on top of the other *.