Fuller's Fantastic Geodesic Dome

This lesson was created as a supplement to the *Fuller's Fantastic Geodesic Dome* program at the National Building Museum. It is designed to be used in your classroom independently, or as an activity before or after a school program at the Museum. For more information about and to register for the National Building Museum's school programs, visit http://www.nbm.org/schools-educators/school-visit/.

The *Fuller's Fantastic Geodesic Dome* program teaches fifth through ninth grade students about principles of engineering and design. Through studying geodesic domes, students are exposed to an innovative solution to the ongoing challenge of creating structures—how to maximize space while creating a strong, cost-effective, people-friendly structure. By studying the geodesic dome and its construction, students learn about materials, structures, and forces present in all buildings.

National Building Museum

Created by an act of Congress in 1980, the National Building Museum explores, celebrates, and illuminates achievements in architecture, design, engineering, construction, and planning. Since opening its doors in 1985, the Museum has become a vital forum for exchanging ideas and information about such topical issues as managing suburban growth, designing and building sustainable communities, and revitalizing urban centers. A private, nonprofit institution, the Museum creates and presents engaging exhibitions and education programs, including innovative curricula for school children.

Over the past two decades, the Museum has created and refined an extensive array of youth programming. Each year, approximately 50,000 young people and their families participate in hands-on learning experiences at the Museum: 2-hour-long school programs for grades K–9; major daylong festivals; drop-in family workshops; programs helping Cub and Girl Scouts earn activity badges; and three innovative outreach programs, lasting between 30 and 60 hours, for secondary school students. The Museum's youth programming has won the Washington, D.C., Mayor's Arts Award for Outstanding Contributions to Arts Education and garnered recognition from the National Endowment for the Arts.

NATIONAL BUILDING MUSEUM
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202.272.2448/www.NBM.org
Red Line Metro, Judiciary Square

Shapes and Solids: Investigating Triangles, Squares, Pyramids, & Cubes

In this lesson students will examine different shapes and materials to determine their strength and suitability when building structures. Students will come to understand that the strength of a material does not depend only on the composition of the material itself; changing a material's shape can also affect the way it resists forces. Likewise, a structure's location or function in a building may determine the shape it takes.

OBJECTIVES

Students will:

- create and examine three two-dimensional shapes — a square, a triangle, and a rectangle — and determine which is the sturdiest;
- discover how changing a material's three-dimensional shape can increase its strength; and
- identify points of compression and tension within geometric shapes.

MATERIALS (PER STUDENT)

- 1 pair of scissors
- 3 index cards (4 x 6")
- 11 small brass fasteners
- Shapes and Solids Student Worksheet, page 34
- Photocopy of Patterns, page 35

MATERIALS (FOR CLASS)

- Several single-hole punches (they can be shared among students)

NATIONAL STANDARDS OF LEARNING

Mathematics . . . . . . Geometry, Problem Solving

Science . . . . B, E

Social Studies 4

Technology 10

Visual Arts 1

DURATION

Two class periods, 45–60 minutes each

LESSON PROCEDURE

1. Create three two-dimensional shapes—a triangle, a square, and a rectangle—and determine the strongest shape.

2. Create two three-dimensional solids—a cube and a tetrahedron.

3. Evaluate the shapes and solids to determine the strongest ones.

4. Discuss geometric forms.

GEODESIC DOME VOCABULARY

Compression, Cube, Engineer, Form, Pyramid, Structure, Square, Tension, Tetrahedron, Triangle

LESSON PLAN

PART I. Create Three Two-Dimensional Shapes (30 minutes)

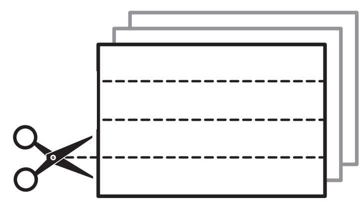
Discussion

1. Explain to students the actual forms from which a structure is made contribute to its overall strength or weakness. Some shapes and solids are stronger or weaker than others.

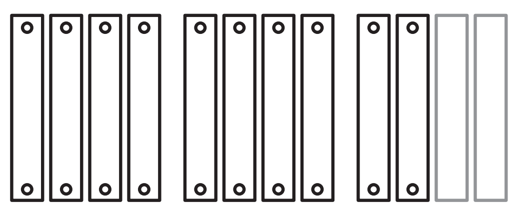
2. Tell students that in this activity, they are going to examine three shapes—a square, a triangle, and a rectangle—and determine what makes the triangle the most rigid.

Action: Shape Comparison

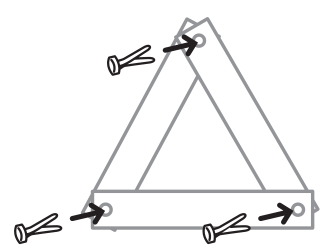
1. Instruct students to cut each index card into four 1-inch strips, lengthwise. They will now have 12 strips, although they will only need 10.



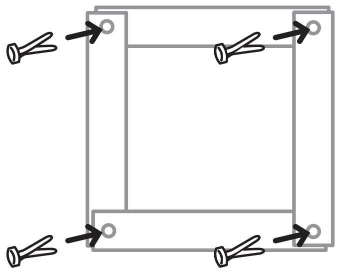
2. Next, have them punch a hole in each end of the 10 strips.



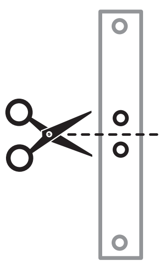
3. To make a triangle, have students connect 3 equal strips with the brass fasteners.

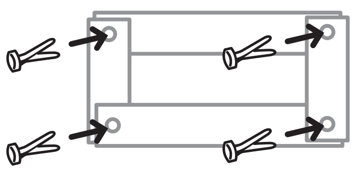


4. Ask them to connect 4 equal strips to make a square.



5. To make a rectangle, instruct students to cut 1 strip in half, widthwise, and punch a hole in the unpunch-ed ends. Have them combine these 2 shorter strips with 2 longer strips to make a rectangle.





6. Now ask students to take the triangle, square, and rectangle and push down on the corners and sides of each shape.

7. What happens? **Answer:** The square and rectangle should collapse; the triangle will keep its shape.

8. Why? **Answer:** The triangle is made up of the least number of sides possible for a geometric shape, locking its three sides into place.

9. Can students identify which parts of the triangle are in tension and which are in compression? **Answer:** If pressure is applied to any of the corners, the two sides radiating from that point will be in compression, while the side opposite that point will be in tension. If pressure is applied to any of the sides, that side will be in tension, while the other two sides will be in compression.

10. Can students add a longer strip to the square and rectangle so that they don't move? **Answer:** Take notice of the shapes they have made inside the square and rectangle; they are triangles.

Discussion

1. Based on the results of this experiment, which shape provides the most structural strength? **Answer:** Triangle

2. Explain to students that geodesic domes get their strength from triangles. Triangles can be arranged into many patterns, which can create different and unique structures.

PART II. Create Two Three-Dimensional Solids and Determine the Strongest Form. (30 minutes)

Just as some two-dimensional shapes are stronger than others, certain three-dimensional solids or forms are stronger than others. For example, a triangular pyramid, or tetrahedron, is more rigid than a square-based pyramid or cube.

Using the patterns for creating cubes and tetrahedrons, ask students to construct both a cube and a tetrahedron. Optionally, the structures can be covered with paper, newspaper, plastic wrap, or foil. Students can decorate their structures with paint, geometric shapes or other designs.

Patterns for creating cubes and tetrahedrons are available on page 35.

1. Copy patterns onto heavy paper.
2. Cut along solid black lines.
3. Fold along dashed lines.
4. Tape edges to create solids.

PART III. Evaluate the Shapes and Solids to Determine the Strongest Ones. (15 minutes)

Test the cubes vs. the tetrahedrons that the students have created. Have students complete the worksheet, page 34. Ask students which solids are sturdier and why. Answers to the worksheet are listed below:

1. **Edges per structure:**

triangle	3	square	4
tetrahedron	6	cube	12

2. **Number of faces per solid, including the bases:**

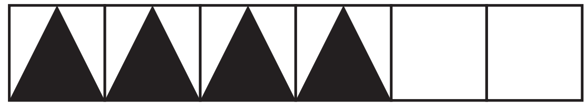
tetrahedron	4	cube	6

3. **Surface area:** answer can be determined by

(a) comparing the computed surface area of each structure:

triangle	.94	square	2.25
tetrahedron	3.75	cube	13.5

or (b) laying pieces of the structures against each other, in 2-D:



PART IV. Discuss Geometric Forms Conclusion (10 minutes)

- Discuss the students findings from the worksheet.
- Ask which structures they would select to build with and why?

To build structures as strong as possible, it makes sense to use triangular forms. However, because squares can provide additional area and blend with human surroundings, like city blocks and furniture, a mixture of both squares and triangles is often incorporated in buildings.

Ask students to consider what kind of buildings they might design if using triangles, squares, cubes, domes, etc. Would the building be a home, a space station, a roller coaster, or a school, etc. How do the answers differ for various structures?

- Domes have curved rather than flat surfaces. Geodesic domes are made of many flat surfaces, usually pentagons and/or hexagons that when combined form curves. The triangles in these forms make them inherently strong. See diagram on page 22.

Shapes and Solids Student Worksheet

NAME:

Which one will win?

It's a test of area, surface strength, and cost.

1. How many edges does your structure have?

________ triangle ________ square

________ tetrahedron ________ cube

2. How many faces does your structure have (don't forget the bases)?

________ tetrahedron ________ cube

3. Which structure has the least amount of surface area?

________ triangle ________ square

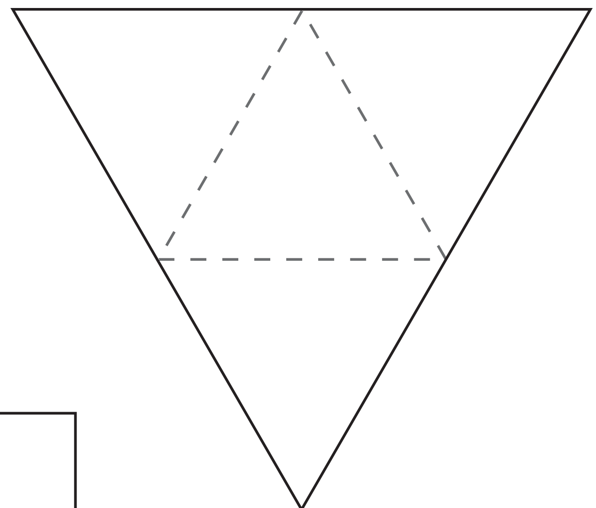
________ tetrahedron ________ cube

4. If you were constructing a building, which structures would you select and why?

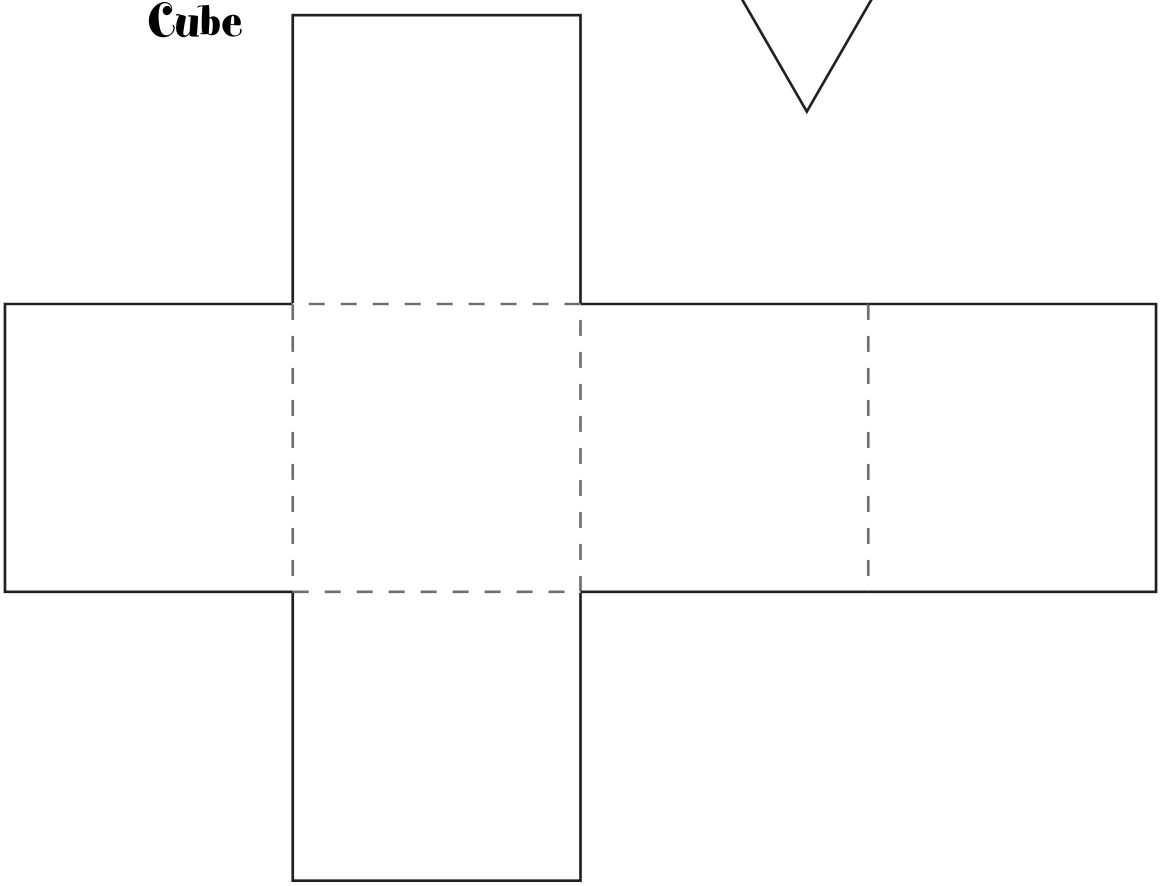
Patterns for Creating Cubes and Tetrahedrons

NAME:

Tetrahedron



Cube



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