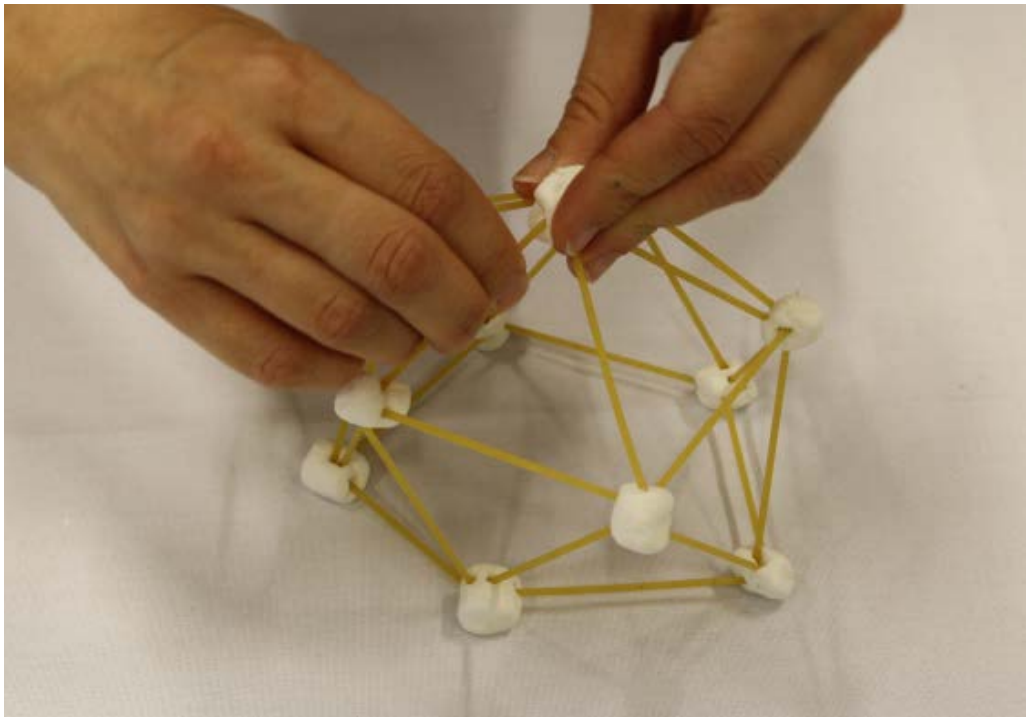
DOME STRENGTH ACTIVITY GUIDE

How much force can a seemingly brittle object withstand when it is dome-shaped?



FOR EDUCATOR

APPLICATIONS IN:

LIFE SCIENCES – Structure and Function/Adaptations

PHYSICAL SCIENCES – Force Distribution/Engineering Principles

NGSS* ALIGNMENT:	Elementary School	Middle School	High School
PS2.A Force and Motion	X	X	
PS3.C Relaionship Between Energy and Forces			X
LS1.A Structure and Function	X		
LS4.C Adaptation	X	X	X
ETS1.B Developing Potential Solution	X	X	X
ETS1.C Optimizing the Design Solution	X	X	X

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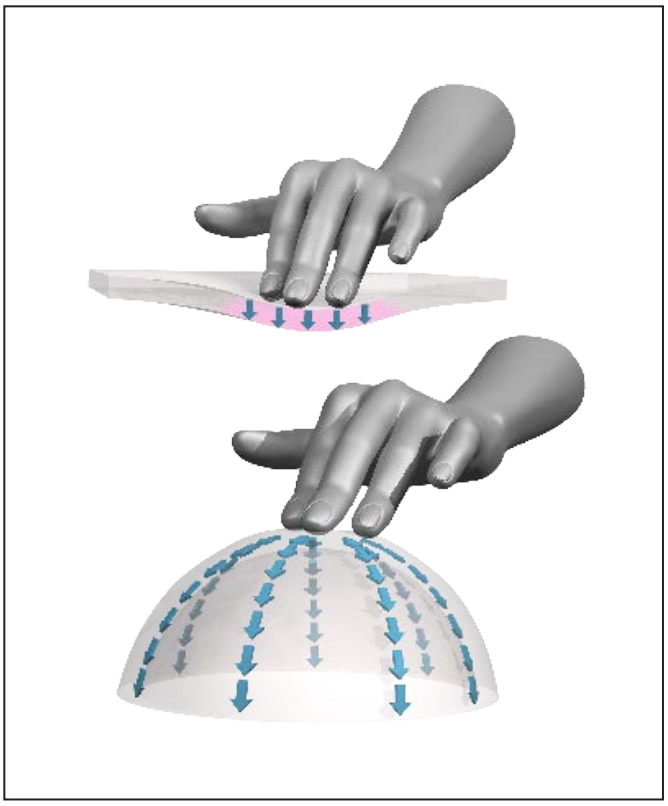
EGGSHELLS AND DOMES - Introduction for Educators

OVERVIEW

Eggshells have a "bad rap" for being brittle. In reality, they are quite strong due to their domed shape. Domes frequently show up in nature in the shape of our skulls, turtle shells, and beetle backs to name a few. Recognizing its strength, humans have incorporated the dome into their architecture for centuries. A flat piece of material will buckle under pressure, but a dome distributes all that force evenly and reducing the load on a single point.



LEARNING GOALS

- Students will compare the strength of domed structures to other structures.
- They will test the strength of eggshells and discuss why they are so strong, explaining it is due to the dome shape.
- Students will design and test their own domes using brittle materials.

HOW TO USE

The materials are segmented specifically for you to use just what you need. You can have students simply explore ideas or follow a more quantitative approach. You can do everything either as a **demo** or **experiment**. We have provided pre-made **"concept overview," "record sheets", "questions to think about"** to use if you wish.

IN GENERAL:

- The activities can get messy. Consider conducting experiments on a plastic tablecloth or inside a large container.

STRUCTURE STRENGTH ACTIVITY:

- Have students test out shapes such as pyramids or house shapes in addition to domes and cubes.
- The domes may collapse slightly when a book is first placed on top of them. Consider complete failure when the book touches the surface.
- Allow geodesic domes and other structures to dry out for at least a night to give them a little more strength.

FOR EDUCATOR

CONCEPT OVERVIEW - Calculating Force

You may wish to calculate force in these activities to quantitatively explain the force upon different structures. Within the activities, mass stacked on top of a set of eggs or geodesic domes can be translated easily into a force. The mass includes that of a plastic plate that creates a flat surface, a bucket placed on top of the plate, and many cupfuls of water. In that case, total mass is:

$$m_{total} = m_{plate} + m_{bucket} + m_{1\ mL} * n_{mL}$$

where n_mL is the total number of mL added to the bucket. Alternatively, you can just measure the bucket of water after it breaks and add the mass of the plate. Once mass is known, you can calculate the force due to gravity:

$$Force\ (F) = m_{total} * g$$

where g is the acceleration due to gravity ($g = 9.8 \frac{m}{s^2}$) and m_{total} is the total mass upon the domes. Make sure you are using consistent units! We recommend using kilograms for mass so the units work out to be Newtons $\frac{kg \cdot m}{s^2}$ — a standard unit of force.

FOR STUDENT OR EDUCATOR

CONCEPT OVERVIEW -
How to Build a Geodesic Dome

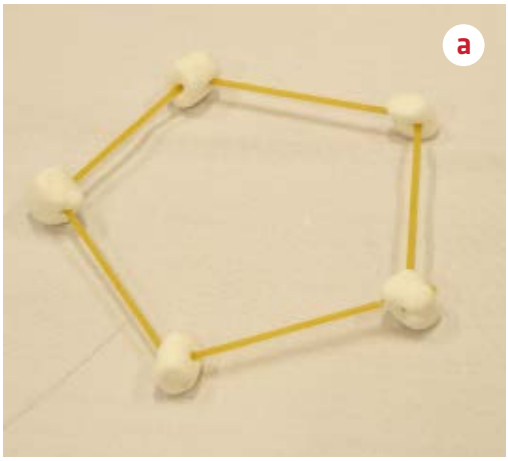
Domes are generally fairly smooth, half-spheres. However, we can build domes out of small, straight, rigid sticks and something to connect those sticks. These types of domes are called "geodesic domes" since they are made out of geometric shapes. Below are instructions to build the simplest of geodesic domes, but they can certainly be far more elaborate. A good example is the Spaceship Earth at Disney's EPCOT.

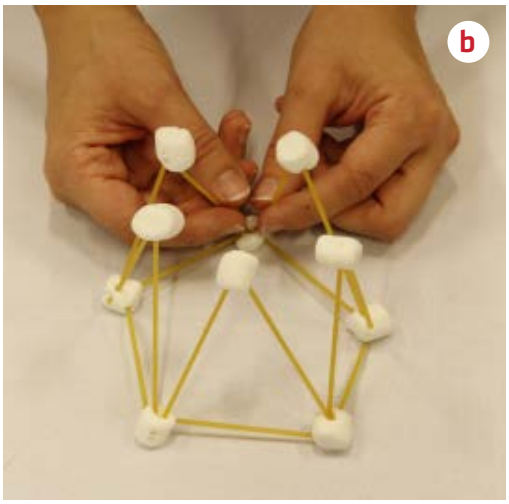
a. Make a pentagon with 5 pieces of spaghetti and 5 marshmallows.

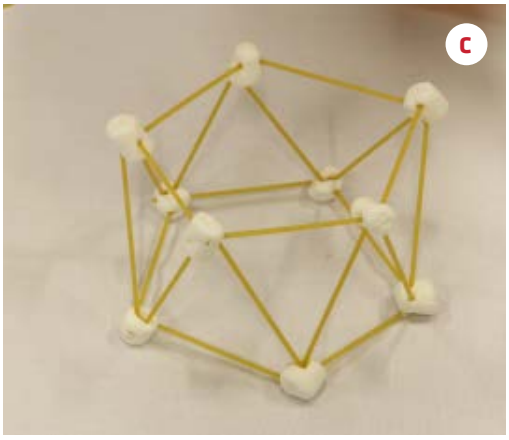
b. Make 5 triangles using 10 more pieces of spaghetti and 5 marshmallows. There should be 2 pieces of spaghetti in each marshmallow.

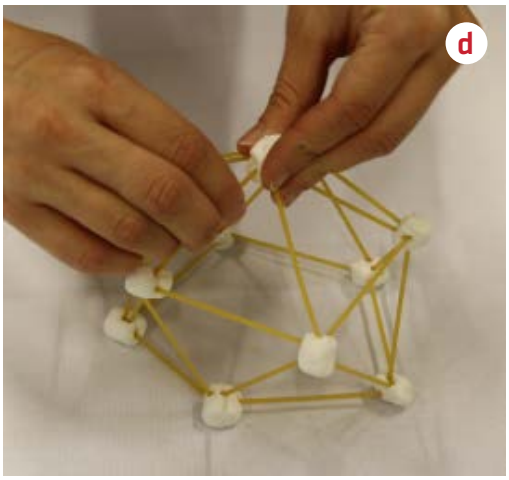
c. Connect the tops of each triangle with 5 more pieces of spaghetti.

d. Stick 1 piece of spaghetti in each of the 5 upper marshmallows and connect them all with another marshmallow.









FOR STUDENT OR EDUCATOR

ACTIVITY –
Geodesic Structure Strength Test

Build different types of structures, including domes and cubes, and compare their strength! Test out other structures that you can think of, such as a pyramid or a house shape.

PREDICT:

Which structure will be the strongest? Why do you think that? How much will that structure be able to handle?

SUPPLIES:

- Marshmallows (you can use gumdrops or gummi bears as well)
- Spaghetti, broken into 3-inch pieces (you can also use toothpicks)
- Plastic Plate
- Bucket
- Water
- Beaker (at least 100 mL)
- Large Tray (to catch water in case it falls)
- Scale

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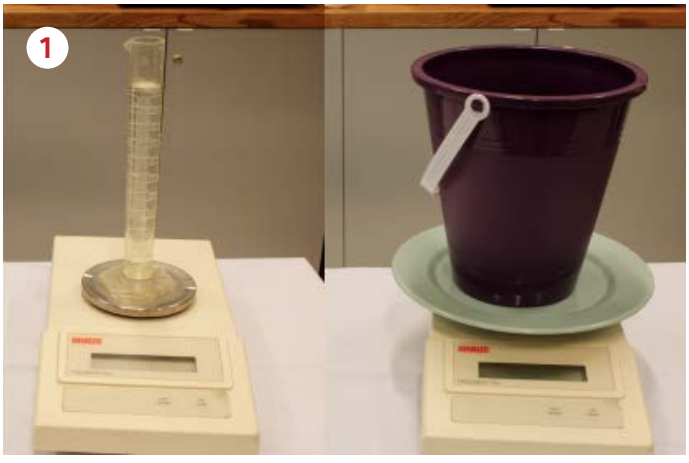
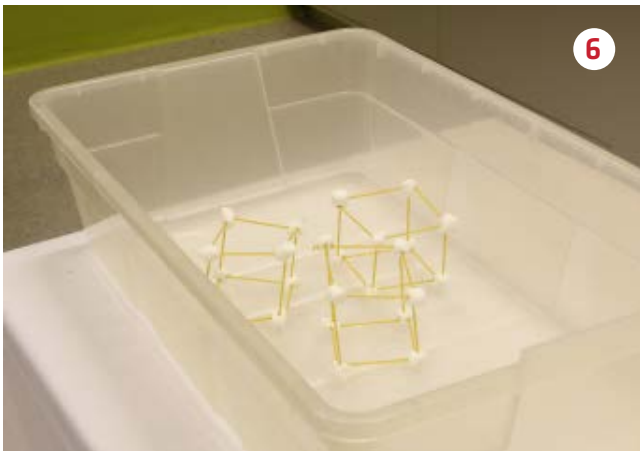
ACTIVITY –
Geodesic Structure Strength Test, *cont'd*

WHAT TO DO:

1) Measure the mass of the paper plate, the mass of 100 mL of water, and the bucket. Record this information.
2) Build three simple geodesic domes out of spaghetti and marshmallows. If possible, let them sit overnight or even several days so they dry out and stick together better. (See: Instructions for building geodesic domes)
3) Align the domes in a triangle inside the tray and place the plate on top. Place the bucket on top of that.
4) Add water 100 mL at a time and record how many times you do this. Keep adding water until at least one dome completely fails (when the plate touches the surface)
5) Using the mass you measured for the plate, the bucket, and the total mass of water (total number of times 100 mL of water added *mass of the 100 mL of water), calculate the force on the three domes at the time of complete failure.
6) Repeat steps 3-6 with cubes built from spaghetti and marshmallows or other shapes you wish to try. Always use 3 structures for each trial.
7) Compare your results for the domes to the other structures. Compare your results to your prediction.





FOR STUDENT

ACTIVITY -
Egg Stress Test

Test the strength of eggs! They have a very common shape seen in nature – the dome! There is a reason for that. What do you think it is?

PREDICT:

How much weight will the eggs be able to handle?

SUPPLIES:

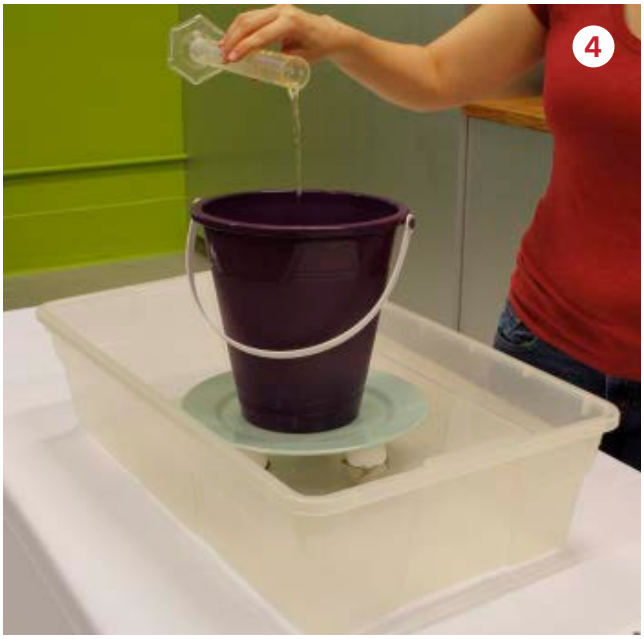
- Eggs
- Egg Carton
- Plastic Plate
- Scissors
- Bucket
- Water
- Beaker (at least 100 mL)
- Scale
- Large Tray (to catch water and egg guts)

FOR STUDENT

ACTIVITY -
Egg Stress Test, *cont'd*

WHAT TO DO:

1) Measure the mass of the plastic plate, the amount of water in 100 mL of water, and the bucket. Record this information.
2) Cut the cups out of the egg carton to act as holders for the eggs. (Cardboard egg cartons are best.)
3) Arrange the eggs in a triangle shape inside the tray. Place the plastic plate onto of the eggs and then the bucket on top of the plate.
4) Add water 100 mL at a time to the bucket and record how many you add. Keep adding water until at least one egg completely breaks (the plate touches the surface).
5) Using the mass you measured for the plate, bucket, and water (total number of mL of water added*mass of 1 mL of water) calculate the total force pushing down on the three eggs when at least one of them broke.
6) Repeat steps 3-6, arranging the eggs differently. Try a smaller or larger triangle or laying your eggs on their sides. Record this information.



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RECORD SHEET – Strength Tests

FOR STUDENT

Use this page for any of the egg strength tests.

Mass of Bucket: _____kg

Mass of Plastic Plate: _____kg

DRAW AND/OR DESCRIBE TEST (include what was being tested such as eggs or dome and how they were arranged such as close together or far apart). Add as much detail as you can.	TOTAL mL OF WATER ADDED	MASS OF WATER (mass of 1mL* number of mL)	TOTAL MASS (WATER + BUCKET+ PLASTIC PLATE)	FORCE (Newtons)

QUESTIONS TO THINK ABOUT - Geodesic Domes

1) How much force could the domes withstand compared to the cubes/other structures?
2) How did your results compare to your classmates'?
3) Why do you think the stronger structures were so strong?
4) Draw a diagram showing how you think the force is distributed over the domes vs. cubes.
5) How would you improve the design of the geodesic dome to make it stronger or sturdier? Why?
6) What are some other examples of domes in nature? Do you have examples of domes in your body? How many can you think of? How many can you come up with as a class?
7) What shape are most buildings in cities? Are they more like cubes or domes? Why do you think that is?

Notes:

FOR STUDENT

QUESTIONS TO THINK ABOUT - Eggs

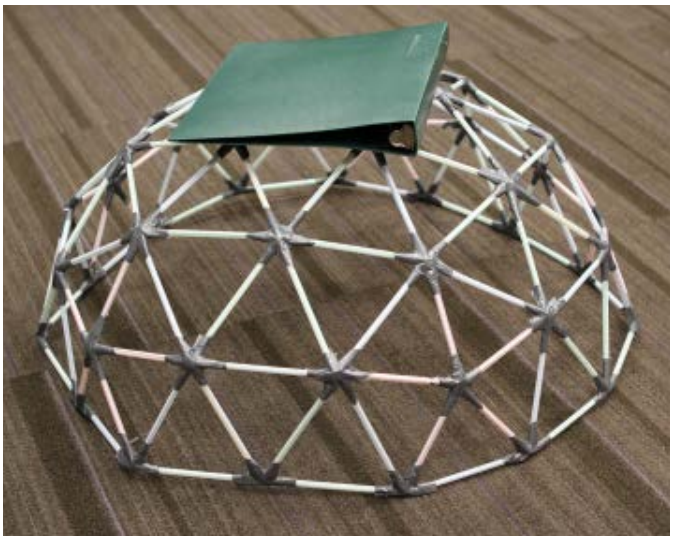
1) Were the eggs stronger or weaker than you expected?
2) How did your results compare to your classmates' results?
3) Why do you think eggs are so strong? Is it due to their material, shape, something else?
4) What did you notice about how the eggs cracked? Was there a pattern?
5) Draw a diagram showing how you think the force is distributed over the egg.
6) What might the evolutionary advantage of a domed egg be for animals?
7) What are some other examples of domes in nature? Do you have examples of domes in your body? How many can you think of? How many can you come up with as a class?

Notes:

FOR STUDENT

DESIGN CHALLENGE

Design a structure using fairly brittle objects (spaghetti, rolled up newspaper, pipe cleaners, straws toothpicks, tape, marshmallows, gumdrops, the possibilities are endless!) and find a means of testing the strength of the structure. To make it more interesting, have a competition in your class and see which dome could hold the most weight. Have a discussion of how the design contributed to the strength of the winning design.



FOR STUDENT

ADDITIONAL RESOURCES

Simple Geodesic Dome Design Ideas on the Web

Building Domes with Newspaper and Tape – PBS, Zoom:
http://pbskids.org/zoom/activities/sci/geodesicdome.html
http://www.pbs.org/wgbh/buildingbig/educator/act_geodesic_ei.html

Building Domes with construction paper:
http://hilaroad.com/camp/projects/dome/dome.html

Building Domes with Skewers – Sci-Toys:
http://sci-toys.com/scitoys/scitoys/mathematics/dome/dome.html

Building Domes with Straws –eHow:
http://www.ehow.com/how_7254371_build-miniature-geodesic-dome.html

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SPECIAL THANKS:

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