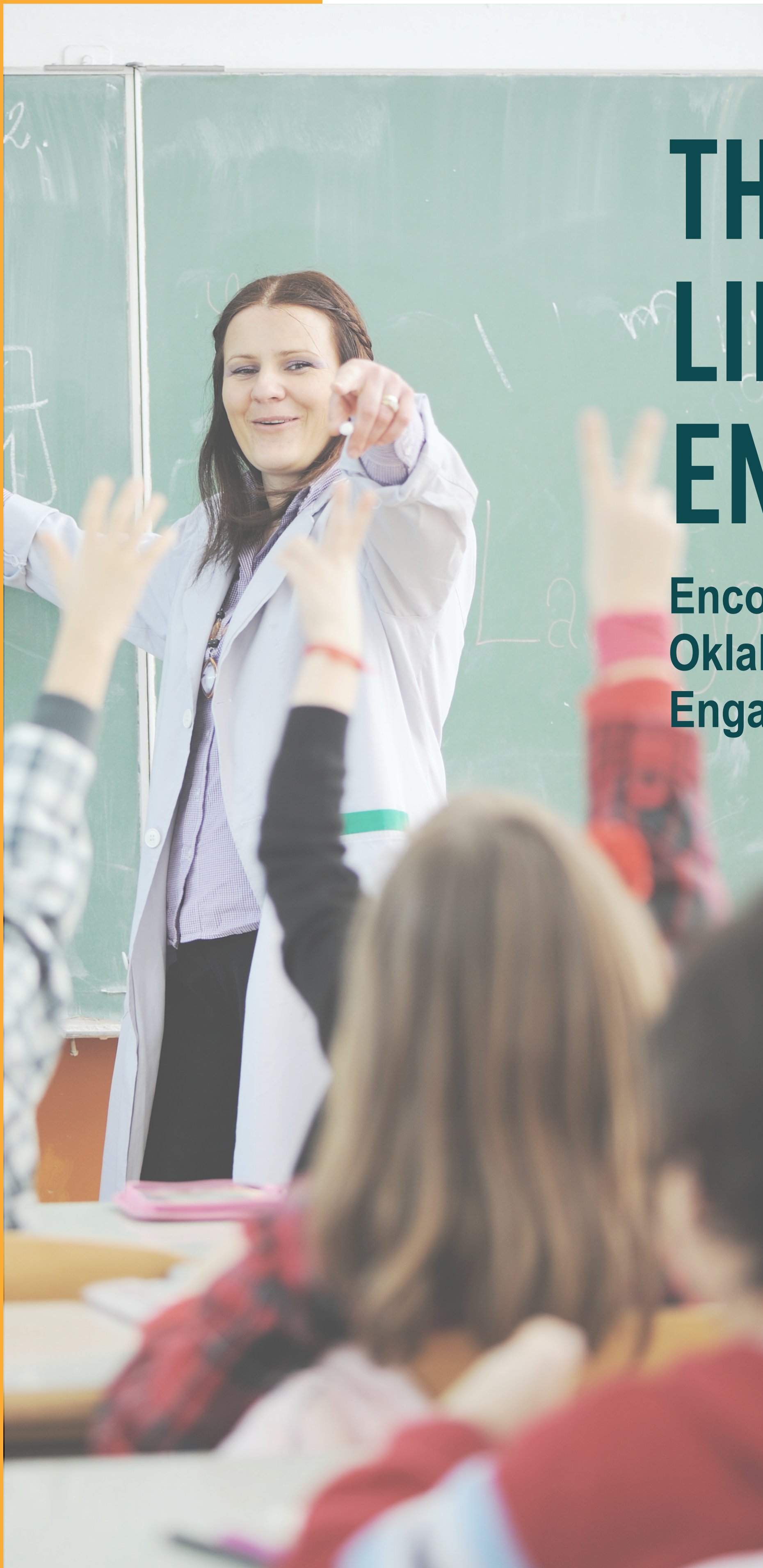

# THINK LIKE AN ENGINEER

## Encouraging Oklahoma Students to Engage in STEAM

OPEN For Business
OKLAHOMA

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WE ARE Oklahoma

AN OPEN FOR BUSINESS OKLAHOMA INITIATIVE

About

# OPEN FOR BUSINESS OKLAHOMA

## We are Oklahoma Initiative

Open for Business Oklahoma (OFBO) is a business association committed to bringing and preserving jobs in Oklahoma communities.

The We are Oklahoma Initiative is designed to demonstrate OFBO members' commitment to the communities in which they work, live and grow. While OFBO businesses are headquartered out of state, businesses are composed of proud Oklahomans dedicated to their local communities. This initiative will be carried out through various community service projects that demonstrate that commitment.

This curriculum has been provided by OFBO members and is available at no cost to the public and to K-12 schools across the state.

For more information, visit www.openforbusinessoklahoma.org.

*Lesson One*

# THE LEANING TOWER OF PASTA

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## OBJECTIVE

Your goal is to test different ways of making structures that are both strong and light.

## BACKGROUND

You will start by measuring the strength of beams made from strands of spaghetti. One strand of spaghetti snaps pretty easily (in fact, you can find out just how much force it takes). What happens when you glue strands together to make multi-strand beams? Does linguine work better than spaghetti? Which beams have the best strength-to-weight ratio? Which beams will be easiest to attach together to build a strong and light structure?

Then, using the components you designed in the first step, build and test a series of at least three structures (outer dimension volume approximately 8000 cm3) and determine which has the best strength-to-weight ratio. You will be testing to see how much weight each structure can bear before collapsing, so the structures will need to have a flat surface on top on which to place the weights.

## KEY TERMS

- Stress
- Strain
- Ductile
- Brittle
- Strength-to-weight ratio

## QUESTIONS

- What is the difference between compressive stress and tensile stress?
- When you hang a weight from the center of a beam which is supported at both ends, what stress(es) do you induce on the beam, and where?
- What geometrical shapes create structures that are both strong and light?

## MATERIALS & EQUIPMENT

- Several packages of uncooked spaghetti (you can experiment with different types like linguine, spaghetti, etc.)
- School glue
- “S”-shaped hook
- Plastic bucket
- Water (or sand)
- Postal scale
- Bathroom scale
- Piece of wood (approximately 25 cm. on a side) to place on top of structure for testing weight-bearing capacity

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## INSTRUCTIONS

1. Do your background research and make sure that you understand the terms and concepts.
2. Choose the best beam design(s) to construct your structures. Find more information on construction if you would prefer a more guided experience at **http://bit.ly/spaghettibeams.**
3. Design and build three different structures with your pasta components.
4. Weigh each structure before testing.
5. Test how much weight each structure can bear before collapsing. Observe carefully and try to identify which component(s) of your structures fail. (Safety note: keep hands and feet clear when testing your structures.)
    - Place the wood platform on top of the structure to be tested.
    - Place the bucket on top of the platform, and slowly add with water (or sand) until the structure gives out.
    - Weigh the bucket, water and wood platform to determine the amount of weight that caused the structure to fail.

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## SUMMARY

Which structure had the best strength-to-weight ratio?

Source: Science Buddies Staff. “The Leaning Tower of Pasta.” Science Buddies, 28 July 2017, https://www.sciencebuddies.org/science-fair-projects/project-ideas/MatlSci_p009/materials-science/build-pasta-tower.

Lesson Two

# DOME SWEET DOME

Think Like an Engineer

## OBJECTIVE

Build a geodesic dome using struts made from rolled-up newspaper and determine the strength-to-weight ratio of the resulting dome.

## BACKGROUND

Have you ever seen a geodesic dome? Geodesic domes are approximately sphere-like (or partially sphere-like) structures made up of interconnected triangles. A famous geodesic dome is Spaceship Earth at EPCOT in Walt Disney World, Florida, but geodesic domes are also commonly found as climbing domes at playgrounds. In this science project, you will get to build a geodesic dome using rolled-up newspapers and tape. How much mass do you think your dome will be able to support? Build one and find out!

## KEY TERMS

- Geodesic dome
- Geodesics
- Surface-area-to-volume ratio
- Volume
- Mass
- Strength-to-weight ratio

## QUESTIONS

- What are the basic shapes used in most geodesic domes?
- How much mass do you think your geodesic dome will be able to support?
- Can you think of some examples of geodesic domes that you have seen or used before?
- Geodesic domes are sometimes used as greenhouses. Why do you think they would be useful for this, or other, specific applications?

## MATERIALS & EQUIPMENT

- 44 sheets of newspaper
- Magazines
- Measuring tape, metric
- Masking tape or painter's tape

## MATERIALS & EQUIPMENT

- Scissors
- Markers
- Optional: Glitter, beads and glue for decorating
- Kitchen or bathroom scale
- A large tray that will fit the geodesic dome on it. This is for weighing the dome on the scale. The dome will have a diameter of about 58 cm. Alternatively, you could use a small cardboard box and weigh the dome upside down with the top in the box, placed on the scale.
- Lab notebook

## INSTRUCTIONS

Make a tube of newspaper by rolling two sheets together, from top to bottom, and taping them in place.

Make 22 tubes total as described in step 1.

To make the short tubes, cut the newspaper tube into three smaller tubes that are 16 cm. long each.

You should end up with 35 long tubes (left) and 30 short tubes (right).

1. Stack two flat sheets of newspaper together. Starting on the top (long) edge, roll the sheets up together as tightly as you can to form a tube. When you reach the bottom edge, tape the tube to keep it from unrolling. The tube should be about 58 cm. long, or the length of the newspaper sheets.

   **Note:** *Newspaper sheets can vary in size. Your newspaper tube does not need to be exactly 58 cm. long to work for this science project; as long as the tube is at least 54 cm. long, you can use the newspaper sheets in this science project. (Tip: The type of dome you are building in this science project is called a 2V.)*

2. Repeat step 1 until you have 22 tubes.

3. Now cut down the tubes to make 35 “longs” and 30 “shorts.” Be careful when using the scissors to cut the tubes.

   - Longs: Cut 12 tubes into three smaller tubes, where each smaller tube is 18 cm. long. Add extra tape to the tubes if needed to keep them rolled up tightly. You should end up with 36 long tubes that are each 18 cm. long (you only need 35 long tubes so you will have one extra).
   - Use a marker to color all of the cut tubes in some visible way, such as by making a colored mark at each end, so you can tell them apart from the short tubes.
   - Decorate the tubes if you like.

   **Note:** *If your original newspaper tubes are less than 54 cm. long, you could use one tube to make only one or two long tubes. (One long tube is 18 cm. long and two long tubes are 36 cm. long total.)*

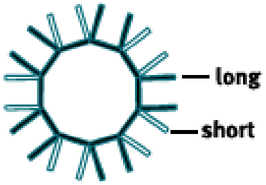
   - To make the long tubes, cut the newspaper tube into three smaller tubes that are 18 cm. long each.
   - Shorts: Cut 10 tubes into three smaller tubes, where each smaller tube is 16 cm. long. Add extra tape to the tubes if needed to keep

them rolled up tightly. You should end up with 30 short tubes that are each 16 cm. long. Use a marker to color all of these tubes in some visible way that is different from the long tubes, such as by making a different colored mark at each end. Decorate the tubes if you like.

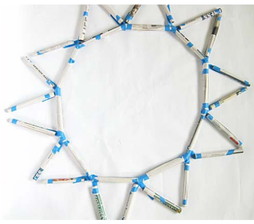
**Note:** *If your original newspaper tubes are less than 48 cm. long, you could use one tube to make only one or two long tubes. (One short tube is 16 cm. long and two short tubes are 32 cm. long total.)*

4. Tape 10 longs together to make the base of the dome.
5. Tape a long and a short to each joint. Arrange them so that there are two longs next to each other, followed by two shorts. On the base you just made, attach a long (dark-colored here) and a short (light-colored here) to each joint, arranging it so that two longs are next to each other, then two shorts, etc.
6. Tape the tops of two adjacent shorts together to make a triangle. Tape the next two longs together, and so on, all the way around.
7. Connect the tops of these new triangles with a row of shorts. The dome will start curving inward. As you continue to add to the dome, you may want to add additional tape to reinforce the joints.
8. At each joint where four shorts come together, tape another short sticking straight up. Connect this short to the joints on either side with longs, forming new triangles.
9. Connect the tops of these new triangles with a row of longs.
10. Finally, add the last five shorts so that they meet at a single point in the center of the dome. Your geodesic dome is now complete! Add additional tape to joints where more support is needed.

Tape together 10 long tubes to make a base like this one.



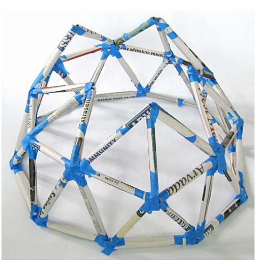

On the base you just made, attach a long (dark-colored here) and a short (light-colored here) to each joint, arranging it so that two longs are next to each other, then two shorts, etc.



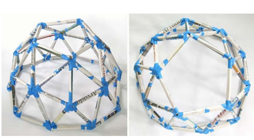
Tape a long and a short tube to each joint, placing two longs next to each other, then two shorts, etc.

Tape the tops of two nearby long tubes together, then the next two short tubes, etc., until you have taped all of the pairs together, making a series of triangles.

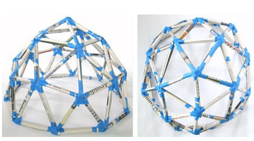
Connect the tops of the triangles with long tubes (10 total).



Where four short tubes come together, tape on another short tube, pointing up, and then stabilize it with a long tube taped to a joint on either side of it.

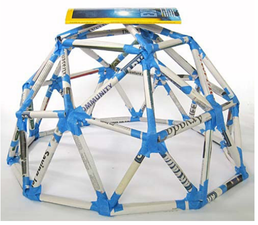


Connect the triangles with long tubes (five total).



Fill in the empty pentagon (five-sided shape) space at the top with five short tubes, meeting at a point in the middle.

## TESTING THE GEODESIC DOME



Test how strong your dome is by adding magazines, one at a time, on the top of it and seeing how many magazines it can support.

1. Weigh your geodesic dome on the scale. Record its mass in your lab notebook.
   - To weigh the dome, place a large tray on the scale, zero out the scale, and then place the dome on the tray.
   - Alternatively, you could place a small, open cardboard box on the scale, zero out the scale, and then place the dome upside down with its top in the box.
2. Test how strong your dome is by seeing how many magazines you can load on top. Add magazines, one at a time, on the top of the dome. Observe the dome carefully for signs of impending failure. In your lab notebook, record how many magazines your dome could support before failing.
3. Weigh the stack of magazines that your dome could support. Record the mass in your lab notebook.
4. What is the strength-to-weight ratio of the dome? In other words, how much mass can the dome support compared to the mass of the dome itself?
5. Did the results surprise you? Why or why not?

Source: PBS Online. (2000). Building Big Educator's Guide, Activity: Geodesic Dome Handout Educational Print and Outreach Department, WGBH Educational Foundation. Science Buddies Staff. "Dome Sweet Dome." Science Buddies, 20 Nov. 2020, https://www.sciencebuddies.org/science-fair-projects/project-ideas/CE_p008/civil-engineering/build-a-dome.

Lesson Three

# DON'T MELT THE ICE

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## OBJECTIVE

Find out which materials will keep an ice cube in a solid state.

## BACKGROUND

Before starting this experiment, read about the states of matter. Guess how long your ice cubes will remain solid when you use the method below to keep them frozen.

## KEY TERMS

- Freezing point
- Solid
- Liquid
- Gas
- Insulator

## QUESTIONS

- At what temperature does ice melt?
- What are the four states of matter?
- What other methods could be used to keep ice in a solid state?
- Why does aluminum foil work to help preserve the ice cube?

## MATERIALS & EQUIPMENT

- Small cardboard box
- Small glass plate or bowl
- Two ice cubes
- Aluminum foil
- Plastic wrap

## INSTRUCTIONS

Place an ice cube in the cardboard box and secure it with tape. Place the other ice cube on the glass plate or bowl. The second ice cube will act as the control.

Check on the ice cubes at half hour intervals until they melt. Record how long it takes for each ice cube to melt completely. How close was your original guess?

## FOLLOW UP

Repeat the experiment. Wrapping the cardbox box with an additional layer at a time of aluminum foil. Record the time it takes for each ice cube to melt with the addition of each layer of aluminum foil. Later, try again but substitute the aluminum foil with plastic wrap. What was the difference in the melting time of the ice cube between using aluminum foil and plastic wrap?

Source: Burgio, Meredith. “How to Prevent an Ice Cube from Melting Quickly” sciencing.com, https://sciencing.com/prevent-ice-cube-melting-quickly-7591701.html.

# FALLEN ARCHES

## The Surprising Strength of Eggshells



## OBJECTIVE

Observe how arches function within a structure.

## BACKGROUND

Arches allow passage through a structure. The shape of the arch distributes the compressive forces to the load-bearing piers that support the arch. This in turn eliminates some tension stresses in the structure.

An eggshell is a natural example of an arch. One end of the shell has a larger, rounder arch, and the other end is narrower and more pointed. It is easy to crack an eggshell if you tap it against a hard surface but if you interlock your fingers and try to squeeze an egg lengthwise to break it, you will find that it can withstand more force than you might expect.

## KEY TERMS

- Arch
- Compression
- Forces
- Tension
- Eggshell
- Mass

## QUESTIONS

- How does the shape of an arch work to support objects on top of, and surrounding, it?
- What are some different types of arches?
- What materials are eggshells made from?

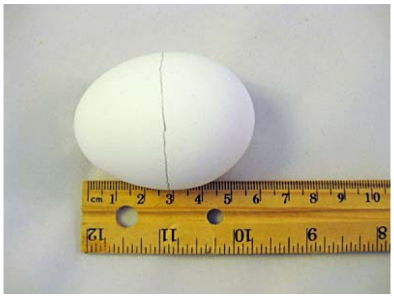
## MATERIALS & EQUIPMENT

- Raw eggs (at least a dozen)
- Ruler
- Pencil or marker
- Bowl, for collecting egg contents
- Small triangular file
- Dinner plate or other large, flat surface to place the eggshells on for testing

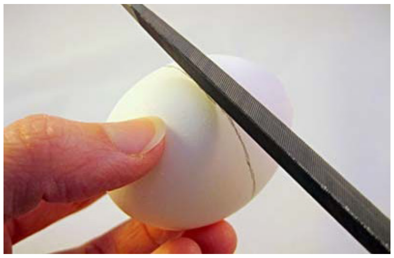
## MATERIALS & EQUIPMENT

- Weights, e.g.:
    - One hardcover book, for the first layer
    - Stack of magazines, to be added one at a time for remaining layers
- Kitchen scale to weigh the book and magazines
- Lab notebook

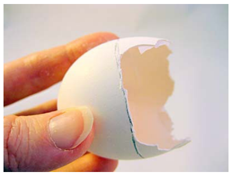
## INSTRUCTIONS



This line is where the eggshell will be cut. It should approximately be at the egg's widest point (width-wise, not lengthwise).



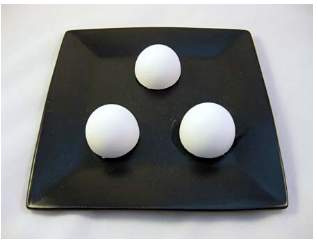
File it enough so that you can easily feel and see a dent.



Carefully break or cut the eggshell back to the scored line you created. Carefully break off small pieces of the shell, working your way around.

Note: It is okay if the edge is a little jagged, but if big chips or hairline cracks develop that go into the more rounded half of the egg, start over with a fresh egg.

Carefully break the eggshell back to the scored line. You will want the rounded half of the egg to end at the scored line.



Place the prepared eggshells on a flat surface, like a dinner plate, with their open end facing down.

1. Use a pencil or marker to mark a line all the way around one of the eggs, dividing the egg halfway between its two pointed ends. Use a ruler to determine the halfway point as you make the line.
2. Carefully crack the eggshell at the pointy end. Make a small hole and drain the contents of the egg into a bowl.
3. Use a triangular file to score the eggshell on your marked line, all the way around. Follow your marked line carefully, and be sure not to hold the empty egg so tightly that it cracks.

    **Note:** *If the egg develops hairline cracks or big chips on the more rounded half, start over (from step 1) with a fresh egg. There should be no cracks or big chips weakening your prepared eggshells.*

4. Repeat these steps to prepare a total of three eggshells. Make each prepared eggshell the same height.
5. Place the prepared eggshells on a flat surface, like a dinner plate, with their open end facing down. The distance between each of the eggshells should be equal with their open ends facing down on the plate.
6. Carefully lay a hardcover book on top of the three eggshells. The book should be centered over the eggshells, so that the mass will be distributed evenly among them.
7. One at a time, carefully add magazines to see how much mass the eggshells can support. Stop adding magazines when the eggshells crack and break.
8. Use the kitchen scale to measure the combined mass of the book and magazines that the eggshells supported without breaking. Depending on how much mass the scale can measure, you may need to weigh the book and magazines individually. Record your results in your lab notebook.
9. Repeat steps 1–9 at least two more times so that you have done your experiment using at least three different sets of eggshells.
10. When you are done with your tests, thoroughly clean any surface the raw eggs (including the shells) touched because they may carry Salmonella. Also, wash your hands thoroughly with soap.
11. Calculate the average mass supported, per eggshell, for each set of eggshells.

12. Calculate the overall average mass supported, per eggshell, by calculating the average for the three sets of eggshells.
13. Make a bar graph of your results. On the y-axis (the vertical axis), put the mass (in grams) that the eggshells supported per eggshell. On the x-axis (the horizontal axis), you can put either all three eggshell sets (as three separate bars) or the average of the three sets (as one bar). If you calculated the standard deviation, you include that on your graph as well.

## SUMMARY

Overall, how much mass could each eggshell usually support? Did you see much variation between your three different eggshell sets? Are your results surprising to you?

Source: Science Buddies Staff. “Fallen Arches: The Surprising Strength of Eggshells.” Science Buddies, 23 June 2020, https://www.sciencebuddies.org/science-fair-projects/project-ideas/MatlSci_p021/materials-science/strength-of-eggshells. Accessed 30 Dec. 2020.

Lesson Five

# KEEPING YOU IN SUSPENS(ION)

## Suspension Bridge vs. Beam Bridge

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## OBJECTIVE

Find out: Can a suspension bridge carry a greater load than a simple beam bridge?

## BACKGROUND INFORMATION

In a **suspension bridge**, the **bridge deck** (the part of the bridge that supports the load, such as cars and their passengers) hangs from, or is suspended by, massive cables. These cables stretch between the bridge's towers, and are securely anchored at each end. The cables are thus under **tension** (they are being tightly pulled on) while the bridge towers are under **compression** (they are being compressed, or pressed down on).

For long spans, the suspension bridge is usually the most economical choice, because the amount of material required per unit length is less than for other bridge types. However, since suspension bridges are relatively flexible structures, stress forces introduced by high winds can be a serious problem.

## KEY TERMS

- Suspension bridge
- Bridge deck
- Tension
- Compression
- Beam bridge

## QUESTIONS

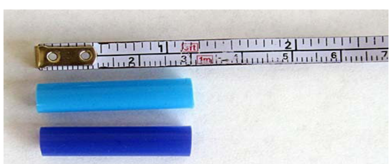
- In a suspension bridge, which parts of the bridge are under compression?
- Which parts of a suspension bridge are under tension?
- How is a suspension bridge different from a beam bridge? Why might they be used in different situations?
- How does an engineer decide which type of bridge to use for a particular site?

## MATERIALS & EQUIPMENT

- Box of drinking straws
- Masking tape or painter's tape
- Thread
- Scissors
- Paperclips, large and small
- Paper cup
- Pennies (at least 350). Alternatively you could use other coins, such as quarters (at least 150), as long as you use all of the same type of coin.
- Metric ruler or tape measure
- Chairs, tables or desks that you can arrange to build a bridge between (2)
- Scale
- Lab notebook

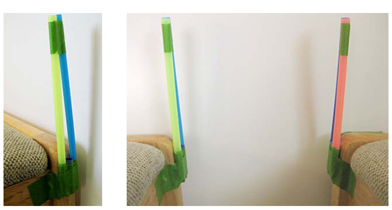
## INSTRUCTIONS

If you are using flexible straws, cut off the short flexible part so you are left with the long, straight piece (on the left in this picture).



Cut two short pieces of straw, each 3 cm. long.

Create a bridge tower by taping two long straws together around a short straw piece on one end. Make two bridge towers this way.



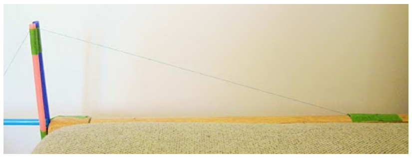
Tape a tower to the edge of a chair, desk, or table. Then, tape the other tower to a different piece of furniture that is the same height. Move the tower positions so that you could fit one long straw between them.

Place a straw between the towers. This straw (in pink here) is the bridge deck and should rest on top of the small straw pieces. You now have a simple beam bridge.

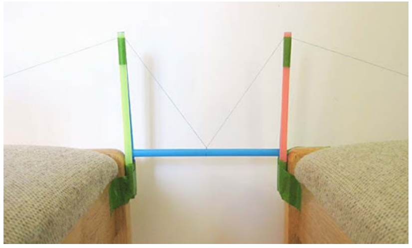
1. If your straws are the flexible type, cut the flexible part off (so that you are left with a long, straight, non-bendable straw piece). Cut 10 straws this way. Make sure they are all the same length; trim some using the scissors if necessary. If you are using flexible straws, cut off the short flexible part so you are left with the long, straight piece.
2. Cut two short pieces of straw, each 3 cm. long.
3. Tape two long straws on either side of one of the short pieces of straw. Do this at one end of the long straws. Then, tape the long straws together at the other end. This is a tower for your suspension bridge. If you are using flexible straws, the "long" straws will be the ones you prepared in step 1, above. If you are using non-flexible straws, use uncut straws for the long straws.
4. Repeat step 3 to create a second tower. Create a bridge tower by taping two long straws together around a short straw piece on one end. Make two bridge towers this way.
5. Tape one tower to the edge of a desk, table, or chair. Tape the second tower to a second piece of furniture at the same height. Position the towers far enough apart so that you could fit a straw between them.
    - If you are using flexible straws, you may need to position the towers about 13 cm. apart.
    - If you are using non-flexible straws, you may need to position the towers about 17 cm. apart.
6. Place another straw between the towers so its ends rest on the short pieces. This straw is the bridge deck. Now you have a simple beam bridge. If you are using flexible straws, use one of the straws you cut in step 1, above, as the bridge deck.

Make a load tester by bending a large paperclip into a V-shape and poking the ends into a paper cup, on opposite sides just below the rim.

Attach the load tester (paper cup) to the bridge deck (the pink straw here) by using a second large paperclip.



Attach each end of the cable to a paperclip and tape the paperclip to the furniture, as shown here (for only the right side of the bridge), so that the cable is tight.



In this picture you can see the middle part of the suspension bridge.The cables are taped to the furniture outside of the picture, to the right and left sides.

Attach the load tester (cup) to the bridge deck (the blue straw here) as you did before.

7. Make a load tester by unbending a large paperclip into a V-shape. Poke the ends of the paperclip into opposite sides of a paper cup, just below the rim.

8. Use a second large paperclip to hang the load tester over the bridge deck. Do this by attaching the two large paperclips together, and then sliding the new one around the bridge deck straw.

9. In your lab notebook, make a data table to compare your results. Add pennies (or other coins, all of the same type) one at a time into the load tester cup. In your data table, record how many pennies the paper cup can hold before the bridge fails. This will be trial 1. Record any other observations you make, such as how the bridge failed, in your lab notebook as well.

   • If you have a scale, you could also weigh the mass of all of the pennies together that caused the bridge to fail. If you do this, make another data table like Table 1 in your lab notebook but instead of "Number of Pennies" label the columns "Mass of the Load (in grams)."

10. Replace the straw that was the bridge deck with a new straw.

    • If you are using flexible straws, this would be one of the other ones you cut in step 1.

    • You are replacing the bridge deck straw because it likely became bent and damaged when the bridge failed.

11. Repeat steps 10–11 at least two more times so that you have done a total of at least three trials using the beam bridge design.

12. Now change the beam bridge into a suspension bridge. Tie the center of a 100 cm. piece of thread (acting as your bridge cable) around the middle of a new bridge deck straw. Place the straw between the towers. Pass each end of the cable over a tower and down the other side.

13. To anchor the suspension bridge, tie each end of the cable around a paperclip. Slide the paperclips away from the towers until the cable pulls tight. Then tape the paperclips firmly to the furniture.

14. Attach the load tester cup and repeat steps 10-12 so that you have tested the suspension bridge design in at least three trials. Be sure to record your results in your data table.

15. Calculate the average number of pennies needed to make each bridge design fail and record your results in your data table. For example, if for the beam bridge it took 180 pennies in trial 1, 190 pennies in trial 2, and 195 pennies in trial 3 to make the bridge fail, the average number of pennies needed to make the bridge beam fail would be 188 (since 180 + 190 + 195 = 565, and divided by 3 equals 188).

16. Make a bar graph of your results. On the x-axis (the horizontal axis) put

the name of the bridge design and on the y-axis (the vertical axis) put the average number of pennies needed for that design to fail.

17. If you weighed the mass of the pennies, you can repeat steps 16–17 to calculate the average mass of the load needed to fail each bridge design and then make a bar graph of your results.

## SUMMARY

Looking at your data and graph(s), which bridge design could hold more pennies? Which bridge design is stronger? Is it a little stronger, or a lot stronger? Why do you think you got the results that you did?

Source: WGBH Educational Foundation. (2001). Building Big: Bridges PBS Online. Retrieved June 13, 2006. Science Buddies Staff. "Keeping You in Suspens(ion)." Science Buddies, 20 Nov. 2020, https://www.sciencebuddies.org/science-fair-projects/project-ideas/CE_p007/civil-engineering/suspension-bridges.

Lesson Six

# MAKE IT MELT

## How Can You Melt Ice Faster?

Think Like an Engineer

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## OBJECTIVE

Which added ingredient will make the ice melt faster? Find out with this easy experiment.

## BACKGROUND

If you live in a place that gets cold in the winter, you have probably seen trucks spreading a mixture of sand and salt on the streets after a snowfall to help de-ice the road. Have you ever wondered how this works? This basic chemistry project can give you some clues.

## KEY TERMS

- Freezing point
- Phases of matter
- Freezing point depression
- Solution
- Solute
- Solvent
- Molecules
- Colligative properties

## QUESTIONS

- What is freezing point depression? When does it happen?
- How are solutions made?
- Which of the suggested test substances are soluble in water?
- Which of the suggested test substances are insoluble in water?

## MATERIALS & EQUIPMENT

- Identical bowls or saucers (4)
- Ice cubes (12)
- Salt (¾ tsp.)
- Sugar (¾ tsp.)
- Sand (¾ tsp.)
- ¼ tsp. measuring spoon
- Timer or clock
- Refrigerator. You will want an empty shelf that can hold all four bowls, unstacked, at the same time.

## MATERIALS & EQUIPMENT

- 50 mL graduated cylinder, or smaller size
- Large cup with a spout, such as some measuring cups. Alternatively you could use a funnel that fits in the graduated cylinder
- Optional: Masking tape and a permanent marker for labeling the bowls
- Lab notebook

## INSTRUCTIONS

1. Get the salt, sugar, sand, and measuring teaspoon ready to use nearby. Once you have set up the ice cubes in their bowls, quickly add the substances to the ice cubes so that they do not melt before adding the substances.
2. Into each of the four bowls, quickly place three ice cubes. Arrange the ice cubes so that only the corners are touching, forming a triangular shape.

   **Tip:** *If you are using ice cubes from a tray, it helps to let the tray sit at room temperature a little (for about five minutes) so that the ice cubes more easily come out of the tray and do not break into pieces.*
3. Carefully sprinkle ½ tsp. of salt over the ice cubes in one bowl. Then sprinkle ½ tsp. of sugar over the ice cubes in another bowl, and ½ tsp. of sand over the ice cubes in the third bowl. Do not sprinkle anything over the ice cubes in the fourth bowl, which will be your control.
4. Move each bowl to an empty shelf in the refrigerator. If any of the ice cubes no longer form a triangular shape in their bowl, rearrange them. You are doing this experiment in the refrigerator because it is easier to see the effects of colligative properties at colder temperatures. Consider why: imagine melting an ice cube on a hot, paved road compared to melting it in the refrigerator. The hot temperature of the road will make all of the ice cubes melt very quickly, which makes it harder to see the relatively minor effects of colligative properties on how fast the ice cubes melt.
5. Note the starting time in your lab notebook. Tell other people who may use the refrigerator that you are doing a science project and to not leave the refrigerator door open long as this could change the temperature of the refrigerator.
6. Check on the ice cubes every hour. When the ice cubes in one of the bowls have become at least half melted, take out all four bowls from the refrigerator. Be sure to take the bowls out before the ice cubes in two or more bowls have completely melted. Depending on how cold your refrigerator is, it may take about four hours for the ice cubes to become at least half melted. While you are waiting, make a data table in your lab notebook.
7. Carefully pour the liquid water from one of the bowls into a cup with a

spout, such as a large measuring cup. Make sure the ice cubes stay in the bowl, but get as much liquid into the cup as possible. Then carefully pour the liquid from the cup into the graduated cylinder. Record how much liquid was in the bowl (the amount of ice melted) in the data table in your lab notebook. After recording your results, clean out and dry the cup and graduated cylinder.

8. Repeat step 7 with the three other bowls. When pouring the liquid from the bowl with the sand, try to leave as much sand in the bowl as possible.
9. Now let the ice cubes completely melt in their bowls (you can leave them at room temperature). Once all of the ice cubes are melted, repeat steps 7–8 (but this time you will not need to worry about keeping the ice cubes in the bowls). Record the amount of liquid remaining in each bowl in your data table.
10. Calculate the total amount of water (originally in ice cube form) that was in each bowl. To do this, add the "amount melted" to the "amount remaining" for each bowl. Record the total amount for each bowl in your data table. For example, if the amount melted was 65 mL and the amount remaining was 25 mL, the total amount would be 90 mL.
11. Calculate the percentage of ice that was melted when you first took the bowls out of the refrigerator for each bowl. Do this by dividing the amount melted by the total amount. For example, if 65 mL was melted, and the total amount was 90 mL, dividing 65 mL by 90 mL would give you 0.72, which is the same as 72%. This means that 72% of the ice melted.
12. Clean out and dry the bowls. Then repeat steps 1–11 at least two more times so that you have done at least three trials total.

## SUMMARY

Did any of the substances you tested consistently speed up the melting of the ice (compared to the melting rate of plain ice cubes with nothing added)? If so, can you explain your results?

Source: Science Buddies Staff. "What Makes Ice Melt Fastest?" Science Buddies, 20 Nov. 2020, https://www.sciencebuddies.org/science-fair-projects/project-ideas/Chem_p049/chemistry/what-makes-ice-melt-fastest.