Expedition Northwest

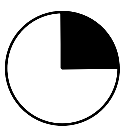
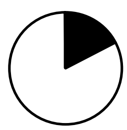
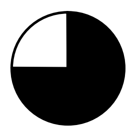
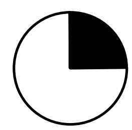
Bridge the Gap

Description: Students construct bridges using marshmallows and toothpicks.

Learning Objectives: Students will investigate what makes a good bridge design.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVEL
Transfer of Energy	Making Models	6
Engineering	Measuring	
Forces	Systems	
Equilibrium	Testing and Experimenting	

TIME REQUIRED

Advance Preparation	Set Up	Activity	Clean Up
			
15 minutes over 3–4 days	**10 minutes**	**45 minutes**	**15 minutes**

SUPPLIES

- Mini marshmallows (50 per student group)
  Note: this is approximately ½ cup per student or a 1-pound bag for every 20 students.
- Round toothpicks (100 per student group)
- Cups (2 per student group)
- Spaghetti style pasta
- Rulers (1 per student group)
- Manila folders, card stock, or cardboard (1 piece per student group measuring at least 8½” by 11”)
- Pennies (500 per class = 10 rolls of pennies)
  Note: 500 pennies will be sufficient if students share; alternatively, each student group has 50 pennies to complete the task)
- Pencil (1 per student group)
- Marker (1 per student group)
- Materials to photocopy: Science Background and Student Procedure (1 per group)

For Demonstration:

- 6 Popsicle sticks or tongue depressors
- 4 brads
- Rubber band
- Tool to make holes in Popsicle sticks (e.g., drill or hammer and nail)

SAFETY PRECAUTION: This lab uses food items, however it is not safe to eat any food in a lab.

Optional:

- Straws
- Clay
- Styrofoam peanuts
- Gumdrops

ADVANCE PREPARATION

- Gather supplies (see supply list).
- Purchase mini marshmallows. A one-pound bag holds approximately 1000 marshmallows; there are about 50 marshmallows in ½ cup.
- Prepare the marshmallows.
- Spread marshmallows on paper towels and air dry for 3–4 days. This gives the marshmallows a stiff texture that is easier to work with and easier to clean up.
- Measure ½ cup portions of marshmallows and distribute into cups.
- Divide toothpicks into cups. Put about 100 toothpicks into each cup.

SET UP

Set out the following materials:

- Cups with marshmallows (about 50 per cup)
- Cups with toothpicks (about 100 per cup)
- Pasta
- Rulers (if not available at student workspace)
- Manila folders, cardstock, or cardboard
- Pennies
- Pencils (if not available at student workspace)
- Markers (if not available at student workspace)

INTRODUCING THE ACTIVITY

Let students speculate before offering answers to any questions. The answers at the right are provided primarily for the teacher's benefit.

Ask the students the following questions in **bold**.
Possible student answers are shown in *italics*.

Put a list of famous bridges on the board. (Include at least one from your area.) Ask the students if they have crossed any of the bridges. Record the results next to the list.

Why do people build bridges?
To cross rivers. To cross canyons. Sometimes roads need to cross each other.

In this activity, you will be designing and building a bridge using marshmallows and toothpicks. Your bridge may be any design, but it must fit the following requirements:

- Your bridge must be at least 25 centimeters long.
- You cannot use more than 50 marshmallows.
- You cannot use more than 100 toothpicks.
- You may use as much pasta as you like.
- Your bridge must have a surface that fits the road that you will be cutting.
- Your bridge must span a gap of at least 10 centimeters.

We will be testing your bridge by placing pennies on the deck of your bridge.

SCIENCE BACKGROUND

Background information can be found at the end of the activity. Print on a separate page for students to read before doing the activity.

Bridge the Gap

Think about the places you have been in the past month. Is it possible to get to any of these places without crossing a bridge? Much of the population in the Pacific Northwest lives near a river, stream or lake, and bridges were built to keep communities connected across these boundaries.

Bridges fall into three different types: **arch bridges**, **beam bridges**, and **suspension bridges**. All three have some similar features. Each has a **deck**, (the horizontal surface you drive on), supported by **piers** (the vertical parts). The **span** is the distance between the piers. **Abutments** support the bridge on either side of the span and connect to the ground on either side. The type of bridge selected for a site will depend on the distance the bridge needs to cover, how much weight the bridge must support, and the natural factors (e.g. wind, earthquakes) the bridge must survive.

An arch bridge has a deck supported by an arch underneath. The arch is built from either side with a **keystone** placed at the center of the arch. The Romans were famous for creating bridges using this design. Some examples of their work still stand today. These bridges are good for shorter spans.

A beam bridge is a horizontal deck surface supported by piers or supports on either side of the stream. One important example of a beam bridge is a truss bridge. A **truss** is a structure made up of triangles. The triangular shape makes a truss very strong for its weight.

Historically, these trusses were made from wood, and to prevent decay, the bridge would be covered. Now, trusses are made of steel to withstand the weather.

TEACHER DEMONSTRATION

The Power of Triangles

For this demonstration you will need:

- Six Popsicle sticks, tongue depressors, or splints
- Four brads
- Rubber bands
- Something to make holes in the sticks (e.g., drill or hammer and nail)

Preparation

- Near the end of each Popsicle stick or tongue depressor, make a hole large enough for the brad to fit into.
- Use four Popsicle sticks and four brads to make a square.
- Use the remaining two Popsicle sticks and a rubber band to make a long cross brace. Fit this cross brace diagonally from one corner of your square to the other so that the holes in the cross brace match where the brads stick through.

Demonstration

- With the four Popsicle sticks and brads connected as a square, demonstrate to students that the square is not stable. The square will collapse into a parallelogram, or even into a flat line.
- Insert the cross brace from one corner of the square to the other. Demonstrate that this structure is now stable and will not collapse.

Explanation

- Dividing the square into triangles gives stability to the square, without adding significantly to construction costs or to the dead weight of the structure.
- The extra cross braces help to distribute the forces throughout the bridge structure.

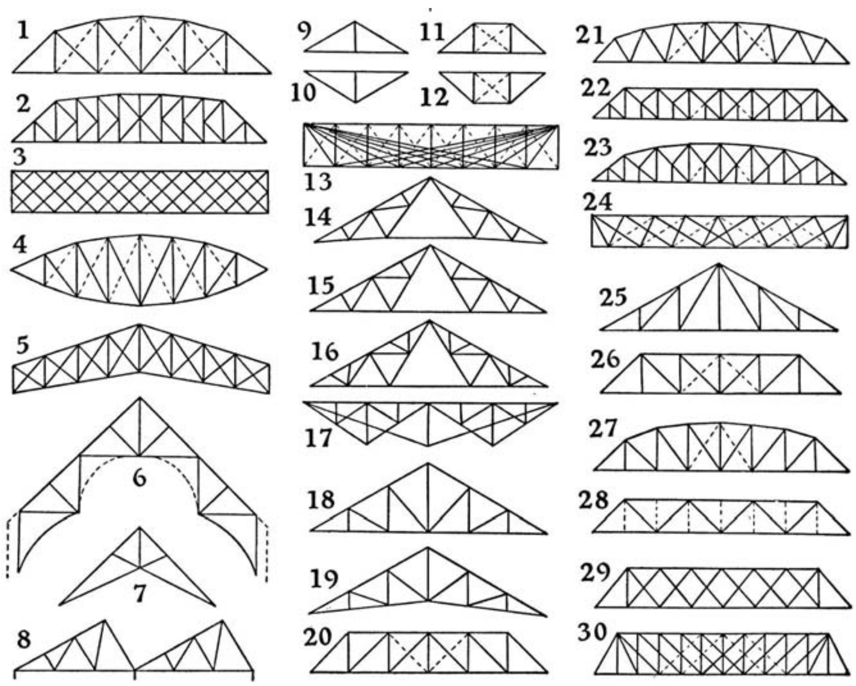
A Tour of Bridges

Collect photos of many bridges to show students different constructions. The greater variety of bridges you can choose, the more ideas students will have to make their own bridges.

Truss Examples

Shown below are a variety of different truss styles. Note that all of these use triangles in their design. Make photocopies of these pictures to show students.

You may wish to construct a sample toothpick/marshmallow truss in advance to get students started.



CLASSROOM ACTIVITY

Students should work in groups of two or three. Each group follows the directions on the Student Procedure sheet. Additional information is given below.

Using stale marshmallows (air dried 3–4 days) instead of fresh marshmallows solves many problems. Because the marshmallows are less sticky, they are easier to work with and clean up. Older marshmallows seem to be better at holding toothpicks. Explaining to students that the marshmallows are old will also discourage students from eating the marshmallows.

Student Procedure: Bridge the Gap

1 **Collect the following construction materials for your bridge:**

- One cup of about 50 marshmallows – count out 50 marshmallows and bring the extras back to the supply area.
- One cup of about 100 toothpicks – count out 100 toothpicks and bring the extras back to the supply area.
- Pasta (you can use as much as you need, start with 10 pieces)
- Ruler
- Sturdy paper or cardboard
- 50 pennies
- Pencil
- Marker
- Scissors

2 **Prepare the road for your bridge.**

- Use a ruler, pencil, scissors, and a piece of heavy weight paper or cardboard.
- Measure and draw a rectangle 25 centimeters long by 15 centimeters wide on your piece of heavy weight paper.
- Cut out the rectangle. This is the road for your bridge.
- With a marker, draw lane markings for your road (down the center of the cardboard lengthwise).

SAFETY PRECAUTION: This activity uses food items, however, it is not safe to eat any food in a lab.

Having pasta available is helpful since it can be broken into any length. It works well as the cross brace in a square of toothpicks. However, it is not as strong, so students will not want to build a bridge exclusively out of pasta.

It is up to you what restrictions you place on students for their bridge building. The goals on the procedure page are reasonable for the amount of materials provided.

You may wish to add requirements for the:
- amount of pennies the bridge can hold (e.g., minimum of 50)
- width of the bridge (e.g., minimum of 15cm)
- height of the bridge (e.g., minimum of 10cm)
- way the bridge looks (e.g., must be visually pleasing)

Encourage students to take inspiration from bridge designs they've seen.

It is also up to you how you test the bridges. You can let students test their own bridges, or you can instruct all students to bring their bridge to you for its strength test.

As an option, collect all student data about the amount of materials they used and how many pennies their bridges held. Use this data during the discussion after the activity. You may want to designate one student in each group to keep track of materials and bridge strength as measured by the pennies.

CLASS DISCUSSION

Ask for student observations. Let students guide the discussion and present their hypotheses before discussing explanations.

Ask the students the following questions in bold.
Possible student answers are shown in *italics.*

Refer to students' data during the discussion of the following questions.

Does there seem to be some connection between the amount of material a group used and the number of pennies their bridge held?
Answers will vary.

Most likely there will be bridges that are "overbuilt," that is they use a lot of materials but don't seem to hold many more pennies. There may also be some bridges that seem really efficient, that is they hold a lot of pennies without using many materials.

Do you think a strength test is a good way to test our bridge designs?
No, cars drive across a bridge, they don't stop in one place like the pennies. Our test doesn't model what will happen to our bridge in heavy winds. Yes, we should measure to find out the maximum weight the bridge can withstand.

OPTIONAL EXTENSIONS

Extension A—Different Materials
Repeat the same activity using different materials. Instead of marshmallows, try gumdrops, clay, or Styrofoam peanuts. Instead of toothpicks, try straws or pasta. Are some materials stronger than others? Are some materials easier to work with?

Extension B—Bridge Contest
Nominate bridges to win prizes in various categories:

- Using the least materials to hold 100 pennies
- Most original bridge design
- Attractive bridge design
- Tallest bridge
- Held the most pennies before collapse

CROSS-CURRICULAR CONNECTIONS

SUBJECT	Activity
HISTORY	**London Bridge is Falling Down** Research and discuss the story behind the children's song.
LANGUAGE ARTS	**Disaster Poetry** Read poems by William McGonagall about the Tay Bridge and its multiple collapses.
SOCIAL STUDIES	Research history of famous bridges to discover the impact their construction had on the community.
MATH	**Materials Study** Study the amounts of materials different bridge designs used and the number of pennies those bridges held. Try to answer and defend the following questions: • Is bigger better? • Is it better to have more marshmallows or more toothpicks? • Is there a ratio of toothpicks to marshmallows that seems to be best? **Statistics** How many pennies does the average bridge hold? Students should investigate this question using line plots or histograms. It is important to understand what is the best measure of "average" in this case.

RESOURCES

http://en.wikipedia.org/wiki/London_Bridge_is_falling_down
Encyclopedia article on the history of the nursery rhyme "London Bridge is falling down."

http://www.mcgonagall-online.org.uk/
Information on poet William McGonagall, whose most famous poem is about a bridge disaster!

http://www.jhu.edu/~virtlab/bridge/truss.htm
Be your very own bridge designer! Design a truss and place a load to calculate the tension and compression forces at work.

http://www.portlandbridges.com/viewphotosall-0-36-cat-1-1.html
Information about the bridges in Portland and around the world!

http://www.bridgestories.com/
The website of Sharon Wood Wortman, bridge expert and tour guide of Portland bridges.

http://www.enm.bris.ac.uk/anm/tacoma/tacoma.html
The Tacoma Narrows bridge in Washington State failed disastrously. After this, all bridge designs are tested in wind tunnels.

http://video.google.com/videoplay?docid=7165319145385181600
Video of the Tacoma Narrows bridge falling into the water.

GLOSSARY

Abutments:	On either side of the bridge, these connect the span to the ground.
Arch bridge:	A bridge using an arch underneath the deck for support.
Beam bridge:	A bridge supported by piers and a horizontal beam to support the deck.
Compression:	A force that shortens structural members, pushing them together.
Dead weight:	How much the bridge weighs.
Deck:	The road/sidewalk surface of a bridge.
Keystone:	The central, wedge-shaped stone at the top of an arch that locks the arch together.
Load:	The weight of the vehicles and people that cross a bridge.
Piers:	Vertical supports of the bridge, these provide a base for the bridge deck.
Span:	The distance between the two piers or other vertical supports.
Suspension bridge:	A bridge with cables suspended from tall piers. The cables hold the deck in place.
Tension:	A force that lengthens structural members, pulling them apart.
Truss bridge:	Type of beam bridge that contains a structure made of triangles.

Bridge the Gap

Think about the places you have been in the past month. Is it possible to get to any of these places without crossing a bridge? Much of the population in the Pacific Northwest lives near a river, stream, or lake, and bridges were built to keep communities connected across these boundaries.

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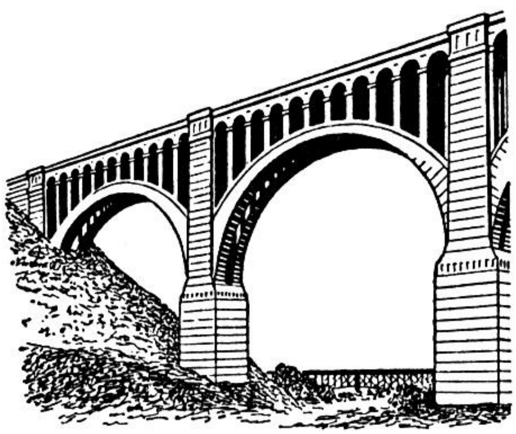

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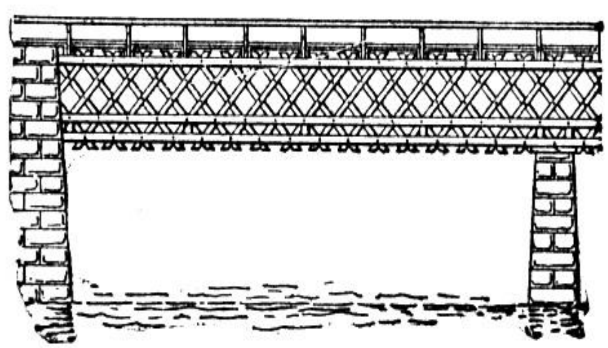
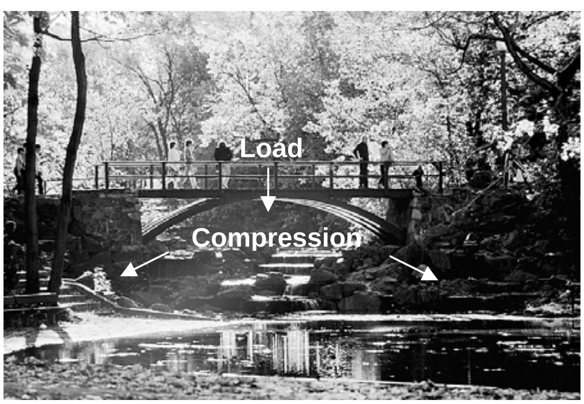
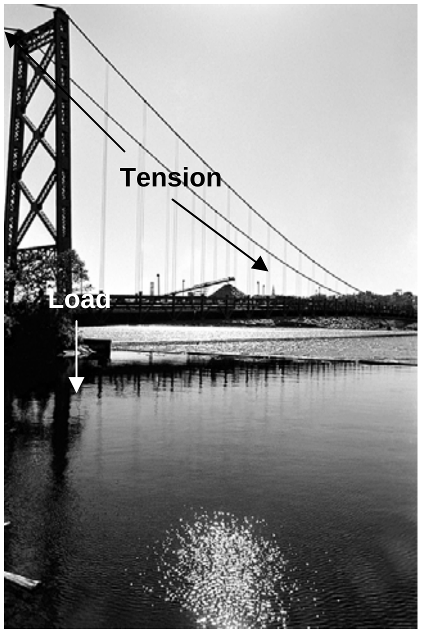


The last type of bridge is a suspension bridge. This type has a horizontal deck suspended from cables that are connected to tall piers. These bridges can span up to 7,000 feet in length. The Incas created suspension bridges made with rope before European colonization occurred in the 1500s. More recent examples of suspension bridges include the Golden Gate Bridge (in San Francisco, CA), the Brooklyn Bridge (in New York, NY), and the Tacoma Narrows Bridge (in Tacoma, WA).

Bridges must be very strong. First, a bridge must support its own weight, called **dead weight.** It must support also vehicles and people moving over it every day. This is called the **load**. A bridge must be able to withstand the forces of tension and compression acting on it. **Tension** is the force that pulls apart or lengthens a part of the bridge, and **compression** shortens or pushes on a part of a bridge. Finally, a bridge must handle the wind, rain, or other natural forces in the area where it is located.

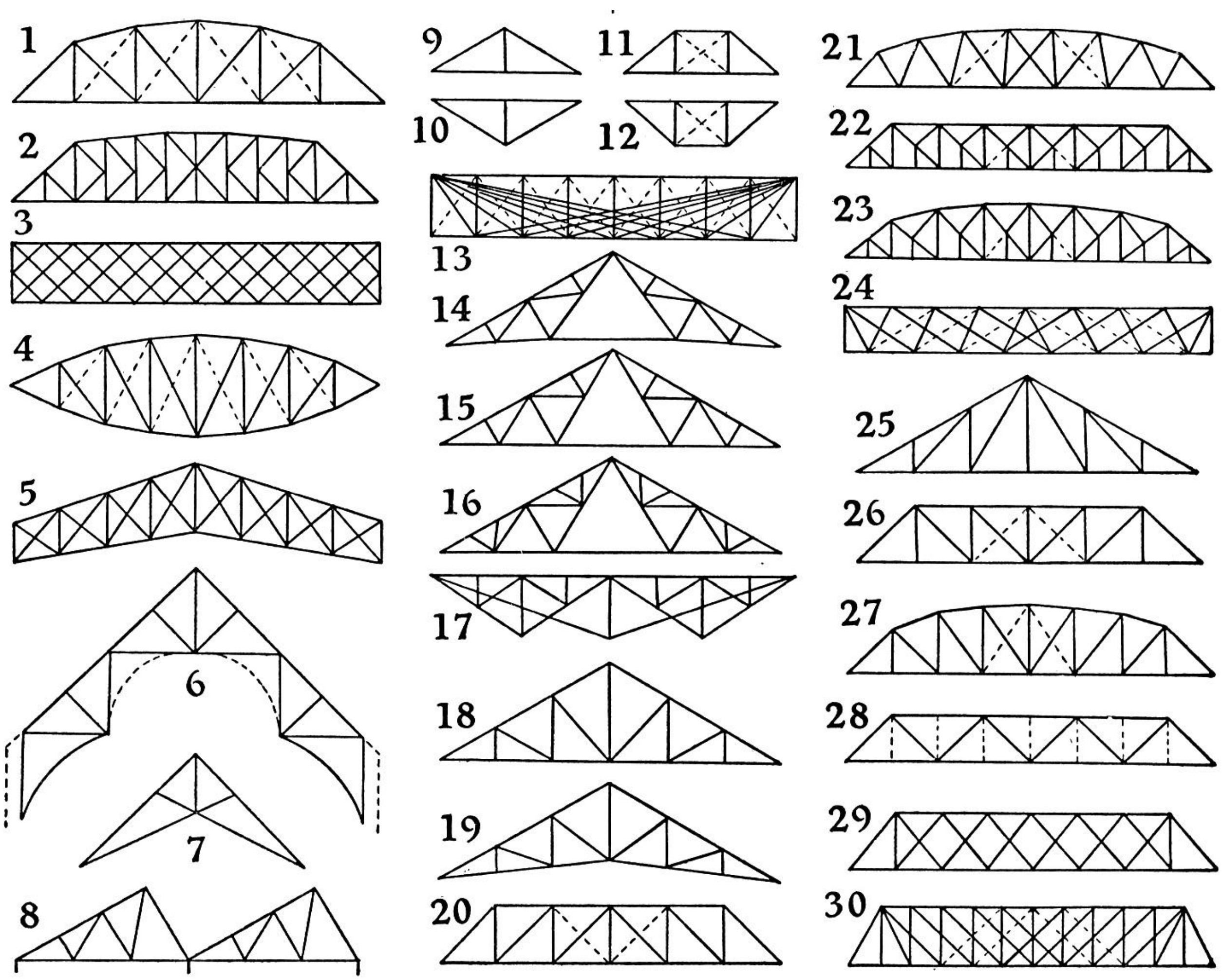
Examine the diagrams below, and observe how the tension and compression forces are different for each kind of bridge.





These pictures show how tension and compression work with each of the different bridge types. In the arch bridge, (previous page, left) compression is pushing outward toward either side of the arch. In the truss bridge, (previous page, right) compression is seen across the top, and tension is felt across the bottom of the span. Tension affects the length of the cables of the suspension bridge (left).

Fayez Hjouj (f-eye-EZZ ha-ZHOOZH) works with bridges every day. As the Bridge Operations Administrator for Multnomah County in Oregon, he makes sure all 10 of the bridges in Portland are working. Most of the bridges in Portland are drawbridges; they raise and lower to allow large boats to pass underneath. Fayez decides when to grease and maintain the giant gears and other parts of the bridge machines. He also communicates with everyone who travels over and under the bridges to make sure they all can get to where they need to go. Imagine how life would be different if people like Fayez weren't working to keep bridges working!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Student Procedure: Bridge the Gap

1 **Collect the following construction materials for your bridge:**

- One cup of about 50 marshmallows—count out 50 marshmallows and bring the extras back to the supply area.
- One cup of about 100 toothpicks—count out 100 toothpicks and bring the extras back to the supply area.
- Pasta (you can use as much as you need, start with 10 pieces)
- Ruler
- Sturdy paper or cardboard
- 50 pennies
- Pencil
- Marker
- Scissors

2 **Prepare the road for your bridge.**

- Use a ruler, pencil, scissors, and a piece of heavy weight paper or cardboard.
- Measure and draw a rectangle 25 centimeters long by 15 centimeters wide on your piece of heavy weight paper.
- Cut out the rectangle. This is the road for your bridge.
- With a marker, draw lane markings for your road (down the center of the cardboard lengthwise).

3 **As a group, decide how you will construct your bridge.**

- Your bridge must be at least 25 centimeters long.
- Your bridge must span a gap 10 centimeters wide.
- You cannot use more than 50 marshmallows.
- You cannot use more than 100 toothpicks.
- You may use as much pasta as you like.
- The road you cut in step 2 must fit on your bridge.

4 **Construct your bridge.**

- Record how many marshmallows, toothpicks, and pasta strands you use in your bridge.
- Measure the height, length, and width of your bridge.
- Make sure the road fits on your bridge.

5

Test your bridge.

- Use two, equally sized textbooks and place them 10cm apart.
- Place your bridge across the gap. Does it hold?
- Put the road on your bridge.
- Carefully place pennies on the road.
- Continue to place pennies on the road until the bridge collapses.
- Record how many pennies your bridge holds.

Record Data Here:

Length __________

Width __________

Height __________

Number of marshmallows __________

Number of toothpicks __________

Number of pasta strands __________

Number of pennies held by bridge __________