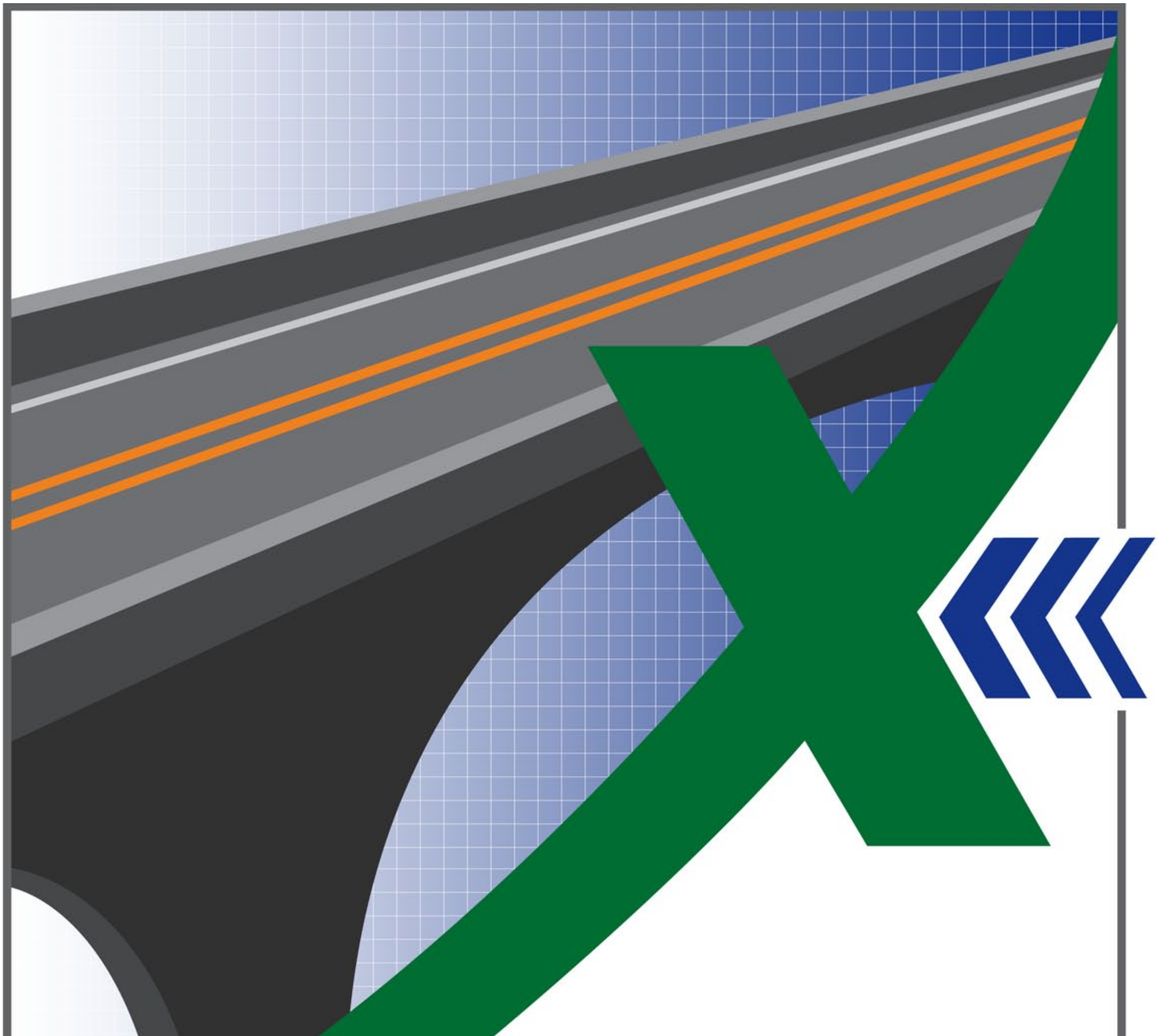


# Design Challenges in the Developing World

TechXcite Discover Engineering

Youth Handouts

# Activity 1: Lighting Without Electricity

Name: ______________________________ Date: ______________

## Materials List

- Corrugated cardboard box
- Plastic bottle
- 4 Binder clips
- Scissors
- Clear packaging tape
- Water
- Paper towels
- Photoresistor
- Digital multimeter

## Procedure

Part A: Building the Skylight

1. Carefully cut about 2-3 inches down each corner of your cardboard box.
2. Bring the two longest flaps together so they touch and overlap about one inch. Pinch and secure them using metal clips.
3. Turn the box on its side and trace the edge of your roof on the short side flaps. Cut the flaps inside triangle shapes along this line.
4. Next, trace the bottom of the bottle on the inside of a long flap and cutout the circle to make a hole in the roof for the bottle. Note: Be careful not to make this hole too big at first. You can always cut away more if it's too small.


5. Tape up the roof edges and secure with more clips, if necessary.
6. Place the water-filled bottle, upside down, in the hole and attach with clear tape.
7. Below the water bottle, in the side of the box, create a small hole (1/4" diameter) for the light probe about one inch up from the base of the box. Leave a small flap of cardboard above the hole to shade the opening from overhead ambient light, which may throw off the measurements.

# Activity 1: Lighting Without Electricity

Part B: Creating the Light Probe

8. Carefully bend the metal wire leads of the photoresistor so that it faces away from the pencil when it is taped down. Make sure the two leads are separated so that they don't touch each other.
9. Connect an alligator wire to each lead of the photoresistor. Then tape the alligator wires to the pencil.
10. Using a ruler, place marks on the side of the pencil at 1" intervals.
11. Finally, connect the two free ends of the alligator wires onto the multimeter probes. It doesn't matter which way you hook up the meter; you can swap the two probes and it will work the same.

    You now have a light meter! Can you guess how it works?

Part C: Testing

12. Work as a team. Decide who will hold the light probe, who will hold the multimeter, and who will write down the readings. The person holding the light probe must be sure that the photoresistor faces upwards towards the skylight during all the readings. Don't let the pencil accidentally turn in your hand.
13. Open up the small flap on the side of your building and insert your light probe until it extends 1" inside the building (use the marks you made on the pencil earlier as a guide). Then, record the resistance reading in the table below.
14. Repeat the measurement with the light probe inserted at 2", 3", 4", and 5".
15. Calculate the average of your five readings. Why do you think an engineer or scientist would want to calculate the average value of all the readings?
16. Now let's try to make it better! See if you can find a way to improve how much light the skylight brings inside the building. Remember, lower resistance values are better because the more light that hits the photoresistor the lower its resistance.

| Distance (in) | Resistance (Ω) |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| Average | |

# Activity 1: Lighting Without Electricity

## Exploration Questions

1. What are the pros and cons of using the bottle light built in this activity?

2. How does the Liter of Light design address the potential problems identified in the previous question?

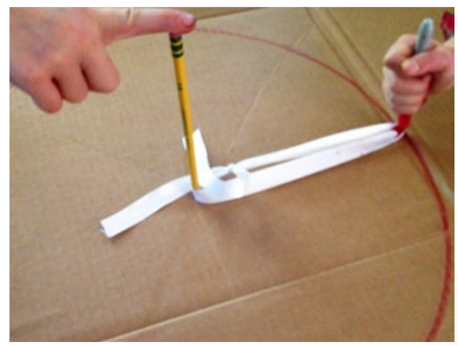
3. What are some other examples of appropriate technology? Why it is appropriate?

# Activity 2: Moving Water

Name: ______________________________ Date: ____________________

## Materials List

- 25 Plastic cups
- Cardboard
- Wooden dowel
- 2 Pencils or pens
- String or ribbon
- Stapler
- Scissors
- Pitcher



## Procedure

1. Before drawing or cutting anything, design your water wheel. How many cups will you use? How will you determine the diameter of your wheel?
2. Once you've finished planning, draw a circle on one of your cardboard pieces. Note: Using 2 pencils and string or ribbon is an easy way to draw the circle.
3. Cut out the circle and push a pencil through the exact center to create a small hole.
4. Trace your first circle onto the other cardboard piece and cut out a second circle. Add a hole to the center of this circle too.
5. Attach cups all the way around the circumference of one of the circles using a stapler. The bottom of the cups should be facing the center of the circle.
6. Put the second cardboard circle on top of the cups. Use a pencil to line up the centers. Staple each cup to the second cardboard circle.
7. Remove the pencil and put a dowel through the center of the water wheel. Then, conduct a preliminary test of your design. The wheel should spin easily on the dowel and shouldn't wobble too much. You may need to adjust the cups or center hole placement.
8. Draw an arrow on one side of the wheel and practice counting the number of revolutions (using the arrow as a reference point).
9. To test your design, two people can hold each side of the dowel or the water wheel can be positioned between two tables. One team member will then slowly pour 2 liters of water into the cups while another team member counts the number of revolutions. Note: If you are testing inside, make sure you have a large bucket to catch the water.
10. If possible, experiment with different pouring speeds, pouring heights, and pitcher location above the wheel. Record your results and related notes in the table below.

# Activity 2: Moving Water

| Trial | Revolutions | Notes |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |

## Exploration Questions

1. How can work be extracted from water using a water wheel?

2. Did the height of the pitcher (when pouring water) effect the number of revolutions? Why?

3. What would you do differently if you were to build another water wheel?

# Activity 3: Types of Bridges

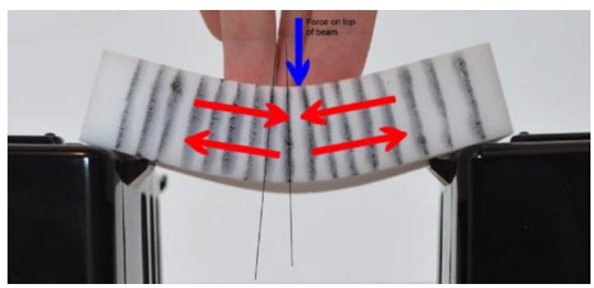
Name: ______________________________ Date: ____________

## Materials List

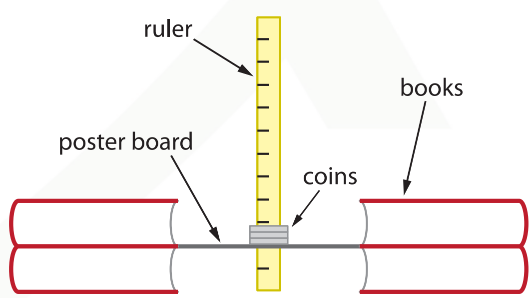
- Large sponge or magic eraser
- Black marker
- Red marker
- Ruler
- Poster board
- 4 Large books
- 10-20 Quarters or 20-40 pennies

## Procedure

1. Create two stacks of books that are approximately the same height and place the sponge with vertical lines drawn on the sides so that it spans the two stacks (see photos below). This is a simple beam bridge. In this example, the sponge represents the beam and the books are the piers.
2. Apply force to the center of the sponge. Notice how the lines on the sponge become closer together on the top and further apart on the bottom. This is because the top of the "bridge" is in compression and the bottom is in tension.

3. Next, take a 14"x3" strip of poster board and place 1 inch of each end between the books to create a beam bridge with a 12" span.
4. One person will hold a ruler at the exact center of the bridge and measure the height of the poster board above the table.
5. Another person will add weights (quarters, pennies, etc) one at a time to the center.
6. After every 5 quarters, take another measurement and record the height in the table below. This can be done until you run out of quarters or until the bridge collapses.
7. Take the other strip of poster board and fold the ends upward at the 1" mark. Tuck the end flaps under the top pair of books and push the piers together so that the bridge creates an arch.
8. Repeat Steps 7-9. What do you notice? Which bridge held the most weight?



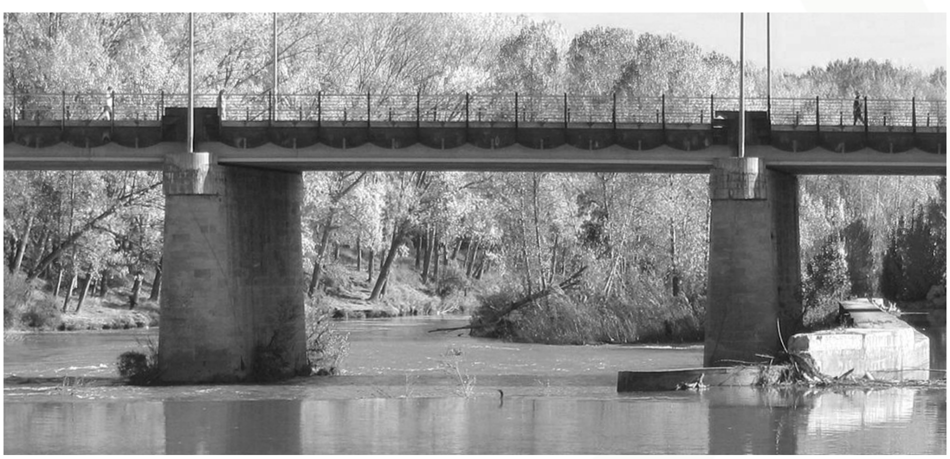
# Activity 3: Types of Bridges

| Weights | Beam Bridge Height | Arch Bridge Height |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

## Exploration Questions

1. Draw arrows on the pictures below to indicate sections of the bridge that are in tension (←→) and sections that are in compression (→←). Identify the type of bridge.

Type of Bridge: ______________________________



Type of Bridge: ______________________________

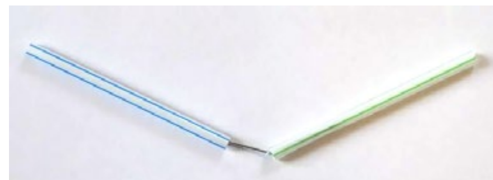
# Activity 3: Types of Bridges

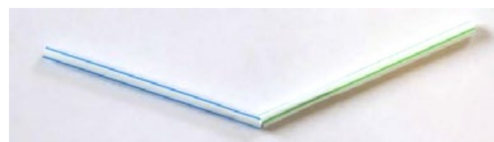
Type of Bridge: ___________________________

2. What materials do you think would work better in compression? What about in tension? Why?

# Activity 4: The Strongest Shape

Name: ______________________________ Date: ______________





### Materials List

- 30 Straws
- 30 Small paper clips
- 2 Cardboard pieces
- Quarters
- Scissors

### Procedure

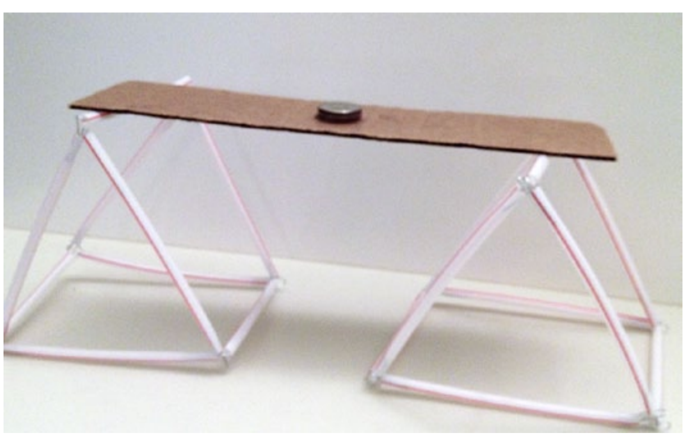
Part A: Exploring Shapes

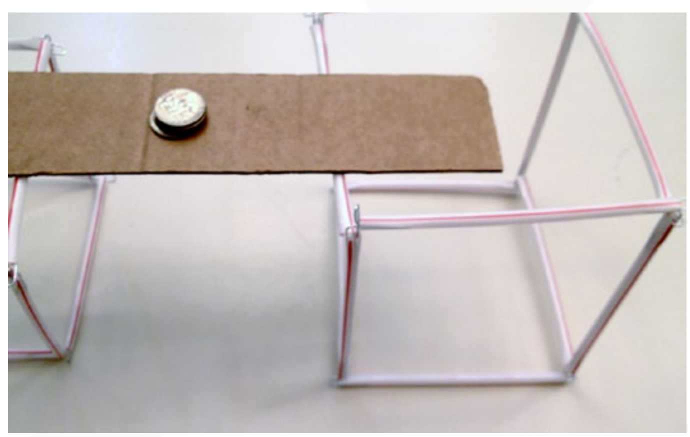
1. Connect two straws together by bending a paperclip and sticking a straw on each end (see photos). This is how you will build your shapes.
2. Use the straws and paperclips to create and explore different shapes. Which is the strongest shape? Why?

Part B: Trusses

3. Create two triangular prisms and two cubes with the paperclips and straws.
4. Use one piece of cardboard to form a bridge between the triangular prisms and the other piece of cardboard to form a bridge between the cubes.
5. Test your triangle-support bridge and square-support bridge by adding quarters, one at a time, to center of each bridge. Record the number of quarters each bridge holds before collapsing.

| | # of Quarters |
|---|---|
| Triangle | |
| Square | |



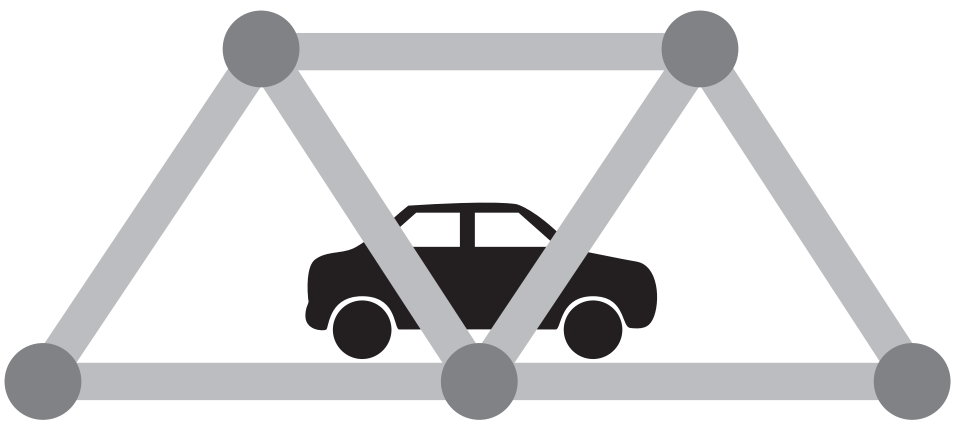


# Activity 4: The Strongest Shape

## Exploration Questions

1. Can you think of places other than bridges where you have seen trusses and triangle shapes used to make things stronger?

2. Draw arrows on the simple truss bridge below to indicate which beams are in tension (←→) and which are in compression (←→).



# Activity 5: Creating a Bridge with Less

Name: ____________________________ Date: ______________

## Materials List

- Wood glue
- 4 Balsa wood pieces (1/8” x 1/8” x 36”)
- Flat balsa wood (1/16” x 3” x 36”)
- Long push pins
- Metal ruler
- Tracing paper
- Corrugated cardboard
- Newspaper
- Hot glue gun and glue sticks
- Pennies
- Scale
- Scissors
- Utility knife
- Calculator

## Engineering Design Challenge

Design a bridge supports the most weight and costs as little as possible to build.

## Design Constraints

- Must be able to span a 60-cm gap
- Bridge cannot be glued (or attached in any way) to the piers
- Must be designed with a safety factor of at least 2
- Only use the materials provided

*Material Costs*

| Item | Cost/Unit (Thousand $) | Unit |
|---|---|---|
| Roadway (1/16” x 3” x 36”) | 20 | 1 Piece |
| Beam (1/8” x 1/8” x 36”) | 5 | 1 Piece |
| Gusset plates | 1 | 10 Plates |
| Wood glue | 14 | 1 Bottle |
| Glue spreading tool | 3 | 1 Paperclip |

# Activity 5: Creating a Bridge with Less

*Waste Costs*

| Item | Cost/Unit (Thousand $) | Unit |
|---|---|---|
| Waste removal | 1 | 0.1 Gram |
| Dumping penalty | 50 | N/A |

## Design & Testing Procedure

Day 1

1. Use a sheet of corrugated cardboard provided by your instructor as a base for planning your bridge. Use a ruler to draw a truss that will be long enough to meet the design requirements.
2. Use tracing paper to trace the truss you designed on the cardboard. Then, place that paper on another piece of cardboard using pushpins. This is the other half of your bridge.
3. Using the ruler, measure how much material you will need so you know how many pieces you will have to buy for the trusses.
4. Buy what you think you will need from the store. Record your purchases on the *Expenses* table.
5. Cover your workspace with newspaper before gluing.
6. Assemble the two trusses on the cardboard. Use the pins to hold the balsa wood in place while gluing.

Day 2

1. Gently remove the two dried trusses from the cardboard.
2. Use wood glue to fix any broken pieces.
3. Design the cross bracing to connect the two halves of the bridge. Make sure to include adequate support (and width) for the roadway. Note: The road cannot be glued to the bridge.
4. You will need to hold the two sides together for about 5-10 minutes until the glue begins to dry. This will be easier if you can brace the sides. Hardback books work well for bracing, but do it carefully. Make sure to protect the books with newspaper.
5. Weigh your balsa wood scrap material and record the waste removal charge on the *Expenses* table. If you did not keep track of your waste, you will be charged a $50K dumping fee instead.
6. Calculate the total cost of your bridge (including the waste) and record.

# Activity 5: Creating a Bridge with Less

Day 3

1. On the last day, your instructor will set up a glue gun station. The glue gun can be used to fix any broken pieces or sections of the bridge that did not dry properly over the last two days.
2. Place the bridge on the supports provided and place the roadway over the bridge. Your instructor will test all of the bridges in front of the class by placing weights (pennies) on each bridge.
3. Calculate your bridge's performance using the formula below. Record each group's data and overall performance score on the *Bridge Performance* table provided below.

**Performance = Max Number Pennies the Bridge Held / Total Cost**

*Expenses*

| Item | Cost/Unit (Thousand $) | Units | Cost (Thousand $) |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | TOTAL COST | |

*Bridge Performance*

| Group | # Pennies | Total Cost (Thousand $) | Performance |
|---|---|---|---|
| *Example* | *400* | *100* | *4* |
| | | | |
| | | | |
| | | | |

# Activity 5: Creating a Bridge with Less

## Exploration Questions

1. What is factor of safety and why is important?

2. What was your performance score? List two changes you would make to your design that would improve its performance.