Investigation 1

Exploring Data Patterns

People in many professions use data and mathematical reasoning to solve problems and make predictions. For example, engineers analyze data from laboratory tests to determine how much weight a bridge can hold. Market researchers use customer survey data to predict demand for new products. Stockbrokers use algebraic formulas to forecast how much their investments will earn over time.

In several previous *Connected Mathematics* units, you used tables, graphs, and equations to explore and describe relationships between variables. In this investigation, you will develop your skill in using these tools to organize data from an experiment, find patterns, and make predictions.

1.1 Testing Bridge Thickness

Many bridges are built with frames of steel beams. Steel is very strong, but any beam will bend or break if you put enough weight on it. The amount of weight a beam can support is related to its thickness, length, and design. To design a bridge, engineers need to understand these relationships.

Getting Ready for Problem 1.1

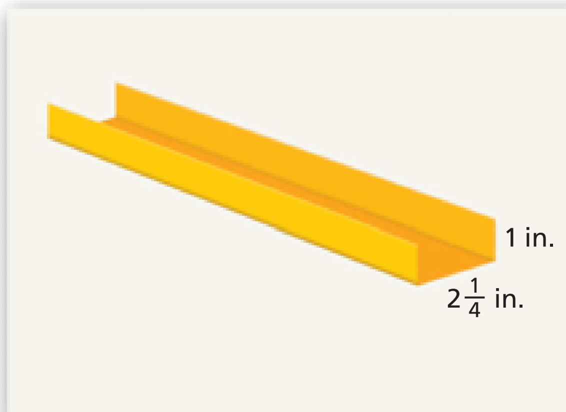
- How do you think the thickness of a beam is related to its strength? Do you think the relationship is linear?
- What other variables might affect the strength of a bridge?

Engineers often use scale models to test their designs. You can do your own experiments to discover mathematical patterns involved in building bridges.

Instructions for the Bridge-Thickness Experiment

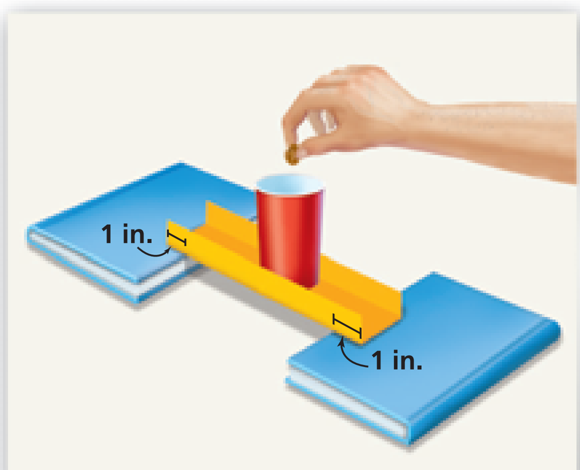
Equipment:

- Two books of the same thickness
- A small paper cup
- About 50 pennies
- Several 11-inch-by-$4\frac{1}{4}$-inch strips of paper



Instructions:

- Start with one of the paper strips. Make a "bridge" by folding up 1 inch on each long side.
- Suspend the bridge between the books. The bridge should overlap each book by about 1 inch. Place the cup in the center of the bridge.
- Put pennies into the cup, one at a time, until the bridge collapses. Record the number of pennies you added to the cup. This number is the *breaking weight* of the bridge.
- Put two *new* strips of paper together to make a bridge of double thickness. Find the breaking weight for this bridge.
- Repeat this experiment to find the breaking weights of bridges made from three, four, and five strips of paper.



Problem 1.1 Finding Patterns and Making Predictions

A. Conduct the bridge-thickness experiment to find breaking weights for bridges 1, 2, 3, 4, and 5 layers thick. Record your data in a table.

B. Make a graph of your (*bridge layers, breaking weight*) data.

C. Does the relationship between bridge thickness and breaking weight seem to be linear or nonlinear? How is this shown in the table and graph?

D. Suppose you could split layers of paper in half. What breaking weight would you predict for a bridge 2.5 layers thick? Explain.

E. **1.** Predict the breaking weight for a bridge 6 layers thick. Explain your reasoning.

2. Test your prediction. Explain why results from such tests might not exactly match predictions.

active math online

For: Virtual Bridge Experiment
Visit: PHSchool.com
Web Code: apd-1101

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1.2 Testing Bridge Lengths

In the last problem, you tested paper bridges of various thicknesses. You found that thicker bridges are stronger than thinner bridges. In this problem, you will experiment with paper bridges of various lengths.

How do you think the length of a bridge is related to its strength?

Are longer bridges stronger or weaker than shorter bridges?

You can do an experiment to find out how the length and strength of a bridge are related.

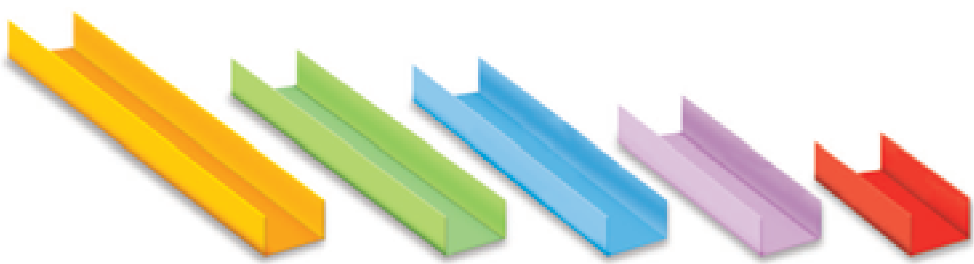
Instructions for the Bridge-Length Experiment

Equipment:

- Two books of the same thickness
- A small paper cup
- About 50 pennies
- $4\frac{1}{4}$-inch-wide strips with lengths 4, 6, 8, 9, and 11 inches

Instructions:

- Make paper bridges from the strips. For each strip, fold up 1 inch on each of the $4\frac{1}{4}$-inch sides.



- Start with the 4-inch bridge. Suspend the bridge between the two books as you did before. The bridge should overlap each book by about 1 inch. Place the paper cup in the center of the bridge.
- Put pennies into the cup, one at a time, until the bridge collapses. Record the number of pennies you added to the cup. As in the first experiment, this number is the breaking weight of the bridge.
- Repeat the experiment to find breaking weights for the other bridges.

Problem 1.2 Finding Patterns and Making Predictions

A. Conduct the bridge-length experiment to find breaking weights for bridges of lengths 4, 6, 8, 9, and 11 inches. Record your data in a table.

B. Make a graph of your data.

C. Describe the relationship between bridge length and breaking weight. How is that relationship shown by patterns in your table and graph?

D. Use your data to predict the breaking weights for bridges of lengths 3, 5, 10, and 12 inches. Explain how you made your predictions.

E. Compare your data from this experiment with the data from the bridge-thickness experiment. How is the relationship between bridge thickness and breaking weight similar to the relationship between bridge length and breaking weight? How is it different?

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Did You Know?

When designing a bridge, engineers need to consider the *load*, or the amount of weight, the bridge must support. The *dead load* is the weight of the bridge and fixed objects on the bridge. The *live load* is the weight of moving objects on the bridge.

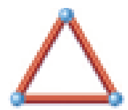
On many city bridges in Europe—such as the famous Ponte Vecchio in Florence, Italy—dead load is very high because tollbooths, apartments, and shops are built right onto the bridge surface. Local ordinances can limit the amount of automobile and rail traffic on a bridge to help control live load.

1.3 Custom Construction Parts

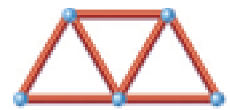
Suppose a company called Custom Steel Products (CSP for short) provides construction materials to builders. CSP makes beams and staircase frames by attaching 1-foot-long steel rods in the following patterns. CSP will make these materials in any size a builder needs.

CSP Beams

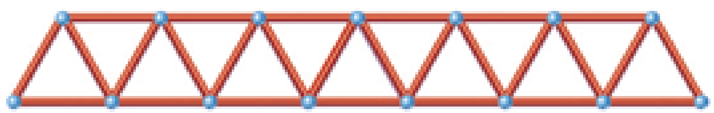
1-foot steel rod



1-foot beam
made from 3 rods

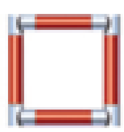


2-foot beam
made from 7 rods

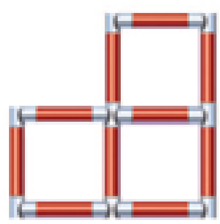


7-foot beam
made from 27 rods

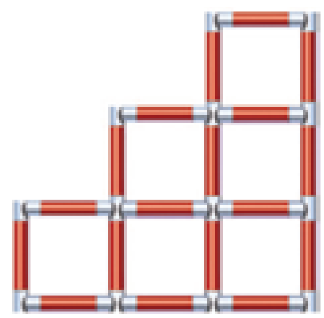
CSP Staircase Frames



1 step
made from 4 rods



2 steps
made from 10 rods



3 steps
made from 18 rods

The manager at CSP needs to know the number of rods required for each design in any size a customer might order. To figure this out, she decides to study a few simple cases. She hopes to find *trends,* or patterns, she can extend to other cases.

Problem 1.3 Extending Patterns

A. 1. Copy and complete the table below to show the number of rods in beams of different lengths. **Hint:** Make drawings of the beams.

CSP Beams

Beam Length (ft)	1	2	3	4	5	6	7	8
Number of Rods	3	7	■	■	■	■	27	■

2. Make a graph of the data in your table.

3. Describe the pattern of change in the number of rods as the beam length increases.

4. How is the pattern you described shown in the table? How is it shown in the graph?

5. How many steel rods are in a beam of length 50 feet? Explain.

B. 1. Copy and complete the table below to show the number of rods in staircase frames with different numbers of steps. **Hint:** Make drawings of the staircase frames.

CSP Staircase Frames

Number of Steps	1	2	3	4	5	6	7	8
Number of Rods	4	10	18	■	■	■	■	■

2. Make a graph of the data in your table.

3. Describe the pattern of change in the number of rods as the number of steps increases.

4. How is the pattern you described shown in the table? How is it shown in the graph?

5. How many steel rods are in a staircase frame with 12 steps?

C. How is the pattern of change in Question A similar to the pattern in Question B? How is it different? Explain how the similarities and differences are shown in the tables and graphs.

D. Compare the patterns of change in this problem with the patterns of change in Problems 1.1 and 1.2. Describe any similarities and differences you find.

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