

# **Bridging Mathematics and Science**

## **6<sup>th</sup> to 8<sup>th</sup> grade Mathematics and Science Activities**

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## Note to Users

The activities in this handout were developed to be used in the unit on bridges which is outlined below. Only those activities which were developed by the authors are included in this handout. Other activities used in the unit can be found by referring to the resources at the end of the handout.

## Unit Outline

Pre-assignment – Students will do research by collecting pictures and information on at least three types of bridges.

- Day 1:\* Introduction to Bridges – Short lecture and picture presentation about bridges. Lecture will include new vocabulary words. Students will assist in classifying the six main types of bridges. Students will be given a list of websites to be used during the unit.
- Day 2:\* Students will be asked to read about and discuss the structure of bridges and in particular discuss the Tacoma Narrows Bridge, a structure that failed.
- Day 3: Student Activity: Students will construct a model bridge and explore how the construction affects safety and efficiency of materials.
- Day 4:\* Activity recap and short lecture about Suspension and Cable-Stayed Bridges and three kinds of Forces – Tensile, Compressive and Shear Force.
- Day 5:\* Short lecture on beams and trusses. Group Hands-on-activity introducing the concept of deflection. Students will set up the apparatus, collect and record data during class. As an assignment, students will make a graph. They will model the data in a table, then on a graph.
- Day 6:\* Activity wrap-up. Students will discuss the mathematics (linear relationship) between deflection and force.
- Day 7: Short lecture on strength of materials. Student activity to test for strong shapes, and lamination. Students will set up the apparatus, collect and record data during class. As an assignment, students will make a graph by plotting their results.
- Day 8: Activity wrap-up. Students will discuss the mathematics involving the lamination activity.
- Day 9:\* Activity on the distribution of the load in the supports of a beam bridge. Students will set up the apparatus, collect and record data during class. As an assignment, students will make a graph by plotting their results.

- Day 10:\* Students will use the graphing calculator to graph and analyze their data. Students will perform an extension exercise.
- Day 11:\* Activity wrap-up. Students will discuss the mathematics involved in the Beam activity.
- Day 12:\* Students will construct a Truss Bridge.
- Day 13:\* Activity on the deflection of a beam and truss bridges. Students will set up the apparatus, collect and record data during class. As an assignment, students will make a graph by plotting their results.
- Day 14:\* Activity wrap-up. Students will discuss the mathematics involved in the Truss Bridge. Unit Review.
- Day 15:\* Unit Test.
- Day 16:\* Test Rubric.

\*Note: Activities developed by the authors and included in this handout.

## **Assessment**

Students' understanding of Unit objectives will be assessed by :

Homework assignments  
In-class group activities  
Demonstration of student constructed Bridge Model  
End of Unit Activity Projects  
Unit Test

## **Web Sites**

Information on bridges:

<http://library.thinkquest.org>  
<http://www.iit.edu/~hsbridge/>  
<http://www.howstuffworks.com/>  
[http://bridgepros.com/learning\\_center/](http://bridgepros.com/learning_center/)  
<http://www.pbs.org/wgbh/nova/bridge/>

## Day 1: Structure of Bridges

Bridges span history and have been built, burned, defended, crossed and celebrated by kings, queens and athletes, as well as by those who commute to work each day. People have been fascinated with bridges and their power to bring together what had been separate. Their many sizes and silhouettes reflect the unfolding of mankind's knowledge of technology.

Bridge is a structure used by people and vehicles to cross areas that are obstacles to travel. Engineers have built over lakes, rivers, canyons, busy highways and railroad tracks. Without bridges, people would need boats to cross waterways.

Bridges range in length from a few feet or meters to several miles or kilometers. Bridges must be strong enough to support their own weight as well as the weight of the people and vehicles that use them. They also must resist natural occurrences, including earthquakes, strong winds, and change in temperature. Most modern bridges have a concrete roadway. The roadway is the part of a bridge on which people and vehicles travel.

Most bridges are held up by at least two supports set in the ground. The distance between two adjacent supports is called a SPAN of a bridge. The supports at each end of the bridge are called ABUTMENTS, and the supports that stand between the abutments are called PIERS. The total length of the bridge is the distance between the abutments. Most short bridges are supported only by abutments and are known as SINGLE-SPAN BRIDGES. Most long bridges are multi-span bridges. The MAIN-SPAN is the longest span of a multi-span bridge.

The six main kinds of bridges are: (1) girder bridges, (2) truss bridges, (3) arch bridges, (4) cantilever bridges, (5) suspension bridges, and (6) cable-stayed bridges.



Girder Bridges, which include many highway bridges, are made of beams called girders whose ends simply rest on piers or abutments. The span length of girder bridges ranges up to 1,000 feet (300 meters)



Truss Bridges are supported by frameworks called TRUSSES. The parts of the trusses are arranged in the form of triangles. Such bridges are built over canyons, rivers, and other areas. A truss bridge may have a main span that extends more than 1,000 feet (300 meters). The simplest truss consists of three parts fastened together at their ends to form a triangle.



Arch Bridges are structures in which each span forms an arch. The spans range up to about 1,700 feet (518 meters) long. The arch bridge is one of the oldest types of bridges. Early arch bridges consisted of large stone blocks wedged together to form an arch.



Photo by Steven Richman  
<http://www.richmangalleries.com>

Cantilever Bridges consist of two independent beams called CANTILEVERS that extend from opposite banks of a waterway. The two cantilevers are joined together above the middle of the waterway by a beam, girder, or truss. Cantilever bridges may have spans as long as about 1,800 feet (549 meters). Many cantilever bridges have truss frameworks.



Suspension Bridges are perhaps the most impressive type of bridge because of their long main span and especially attractive appearance. These bridges have a roadway that hangs from steel cables that are supported by two high towers. Most suspension bridges have a main span more than 1,000 feet (300 meters) long. Some have a main span longer than 4,000 feet (1,200 meters).



Photo by Steven Richman  
<http://www.richmangalleries.com>

Cable-Stayed Bridges are different from suspension bridges, their cables are more taut than the flexible cables of suspension bridges. They offer greater stiffness over that of suspension bridges. Cable-stayed bridges are economical for medium span applications in the 500 feet (150 meters) to 3,000 feet (900 meters) range.

### Vocabulary Words

Bridge	A structure spanning and providing passage over a waterway, railroad, or other obstacle.
Span	The extent or measure of space between two points or extremities, as of a bridge
Abutments	A structure that supports the end of a bridge; a structure that anchors the cables of a suspension bridge; that part of a structure that bears the weight or pressure of an arch.
Piers	A supporting structure at the junction of connecting spans of a bridge.
Single-span bridges	Short bridges supported only by abutments.
Multi-span bridges	Long bridges with a main-span.
Main span	Longest span of a multi-span bridge.
Girder bridges	Horizontal beams used as a main support for the structure.
Truss Bridges	Supported by frameworks called trusses.
Arch Bridges	Structures in which each span forms an arch.

- Cantilever bridges     Bridges formed by two projecting beams or trusses that are joined in the center by a connecting member.
- Suspension bridges     Bridges having the roadway suspended from cables that are usually supported by towers.
- Cable-Stayed bridges     Bridges having the roadway suspended from taught cables that are usually supported by towers.

## Day 2: Structure of Bridges

All structures, whether natural or artificial, must be designed to withstand potentially destructive forces. Valuable information about designing structures can be learned from studying those structures that have failed and those that have survived.

The Tacoma Narrows Bridge collapsed on November 7, 1940. It spanned 853 meters across Puget Sound, thirty miles south of Seattle. It had been open only four months. When it opened, the bridge's deck undulated so much, harmless, it was thought, that thrill seekers sought it out to experience the roller coaster like ride across. Many people went miles out of their way to avoid "Galloping Gertie" as the bridge was nicknamed. The Tacoma Narrows span with a roadway, at thirty-nine feet (12 meters), was exceptionally narrow. It was supported by shallow plate girders instead of traditional deep, stiffening trusses was economical and elegant. The bridge had been designed to withstand winds of 195 km/h, but was destroyed by a wind of only 65.6km/h.

The wind caused the deck of the bridge to move up and down in a wavelike motion. The distance between the crest and trough of these "waves" eventually reached 9m. After several hours, the deck began to twist back and forth until some of the suspending cables snapped, plunging part of the bridge into the water. No lives were lost since the bridge was closed after it started to sway.

The bridge failed because the design did not provide a structurally stiff frame to resist moderate winds.

The bridge was well constructed. The design was largely at fault.

The materials were not inferior, but they were too light. At the time, it was believed by engineers that the structure of an expansion bridge should be kept light so that the size of the cables could be minimized.

Wind and the oscillations of the deck of the bridge were the main factors in causing the bridge to collapse.

The main change brought about by this failure was to design a stiffer and heavier deck that is resistant to twisting and to lateral deflection.

The new Tacoma Bridge is built with a warren girder to keep it stable.

Students will discuss the structure of bridges from the collection of pictures they have and also discuss the possibilities of any structure that could collapse and give the specific reasons.

Student assignment: Write six sentences about one of the bridges they have found and give the structure of the bridge and why they chose that particular bridge.

## Day 4: Suspension and Cable-Stayed Bridges

### Suspension Bridges

A suspension bridge is characterized by a cable or series of cables that carry the downward forces to the supports and then down to the ground.

The majestic Golden Gate Bridge is synonymous not only with the San Francisco Bay area but with large-scale suspension bridges. It has a total length of 8,981 feet (2737 meters).



The main support members are parallel cables strung over towers that run the length of the bridge and are anchored at either end. The deck is supported by suspenders that are hung from the main cables. The weight of the bridge is supported by the cables, which are in tension, a pull withstood by their anchorage, and the towers, which are in compression.

### Cable-stayed Bridges

A typical cable-stayed bridge is similar to a suspension in that it is constructed from a continuous girder which is supported by cables. With the cable-stayed bridge however, there are one or two towers erected above piers in the middle of the span instead of a tower at each end of the span.. From these piers, cables are attached diagonally to the girder to provide additional support. The tops of the towers act as the anchor. The weight of the bridge is supported by the cables, which are in tension, a pull withstood by their anchorage at the top of the each tower, and the towers, which are in compression.

Cables for suspension bridges and cable-stayed bridges are made up of strands consisting of thousands of fine wires that have a much higher tensile strength than thicker rods of the same overall cross sections.

There are three types of forces that act on bridges:

- Tensile – causes a material to stretch or pull apart.
- Compressive – causes material to become more compact and pressed together.
- Shear – causes bending or twisting in a material.

## Day 5: Beams and Trusses

Beams are used to span the space between two points. They are used to hold up loads. Beams may be made in different shapes. For the same amount of material, an I-beam has greater rigidity and strength than does a simple beam. A girder beam bridge is essentially a trussed beam. The beam rests on supports that carry the downward forces to the ground. The crossed members of the girder provide strength against shear forces.

Girder bridges, which include many highway bridges, are made of beams called girders whose ends simply rest on piers or abutments. The span length of a girder bridge ranges up to about 1,000 feet(300 meters).

Truss bridges are supported by frameworks called trusses. The parts of the trusses are arranged in the form of triangles. Such bridges are built over canyons, rivers, and other areas. A truss bridge may have a main span that extends more than 1,000 feet (300 meters). The simplest truss consists of three parts fastened together at their ends to form a triangle.

A cantilever is a simple beam that is fixed at one end. Cantilever bridges consists of two independent beams called cantilevers that extend from opposite banks of a highway. The two cantilevers are joined together above the middle of the waterway by a beam, girder or truss. Cantilever bridges may have spans as long as about 1,800 feet (549 meters). Many cantilever bridges have truss frameworks.

### **Deflection of a Cantilevered Beam Activity**

Deflection – the amount that a material bends when a force is applied to it.

Materials:

- Thin, narrow, and long piece of wood (like a meter stick)
- Meter stick for measuring
- Clamps or books (to fasten the wood to the end of a desk)
- Set of standard masses
- String
- Scissors

Procedure:

1. Prepare the data table.
2. Place a meter stick on the desk.
3. Position the meter stick so that at least 50 cm. of the stick hangs over the edge of the desk. (Each team may select a different overhang)
4. Using a clamp, secure the meter stick to the desk.
5. Record the mass of 0 as the first mass into the table.
6. Measure the height of the free end of the meter stick above the floor, using either the top or the bottom of the stick.



7. Record this measurement into the column height of the end without a mass.
8. Record this measurement into the table as the first height of end with mass (mass of 0.)
9. Add a mass to the free end of the meter stick using a string.
10. Record the mass into the table as the next mass.
11. Measure the height of the weighted end of the meter stick using same the reference as in step 6 (top or bottom.)



12. Record this measurement into the table as the next height of end with mass.
13. Fill in the deflection entry by subtracting the height of end with mass entry from the height of end without mass entry.
14. Repeat steps 9 through 13 for several masses.

## **Deflection Data Table**

Names: \_\_\_\_\_

Date: \_\_\_\_\_

Overhang: \_\_\_\_\_ cm.

mass (g).	deflection (cm.)	height of end without mass (cm.)	height of end with mass (cm.)

## **Teacher Notes**

Assignment:

Students will graph the results – the vertical axis represents deflection and the horizontal axis represents force (weight).

Students will discuss the pattern of the points in the graph. They should recognize that the points form a linear pattern:

Using a straight edge, students will draw a “fit” line through these points.

Class results from different overhang amounts will be compared and discussed.

Students should conclude that although all graphs had linear patterns, the slopes of the “fit” lines were different when the overhangs were different. Students should conclude that for the same mass, the deflection is less when the overhang is less; therefore, the slope of the “fit” line decreases as the overhang decreases.

Conclusion:

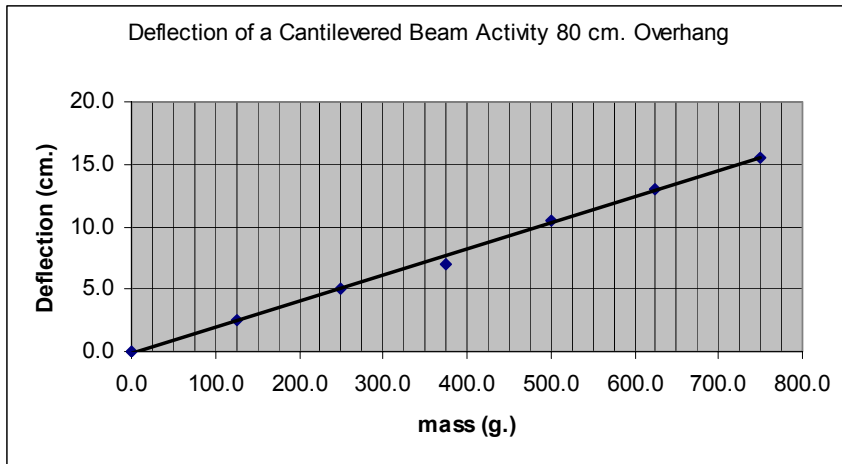
Students’ graphs should show that deflection is proportional to the applied force. The amount of deflection is the same for each equal increment of force that is applied.

## Day 6 : Deflection of a Cantilevered Beam Activity Wrap-Up/Extension

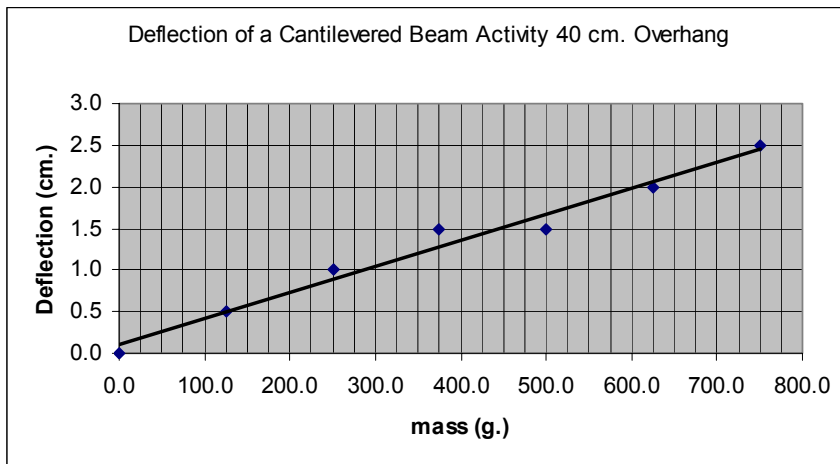
If the length of the wood over the edge of the desk was shorter, what difference in results would you expect? Test your prediction by repeating the experiment – clamping the piece of wood at a different position. Plot the new data on the same graph.

### Sample Results:

80 cm. Overhang			
mass (g.)	deflection (cm.)	height of end without mass (cm.)	height of end with mass (cm.)
0.0	0.0	88.5	88.5
125.0	2.5	88.5	86.0
250.0	5.0	88.5	83.5
375.0	7.0	88.5	81.5
500.0	10.5	88.5	78.0
625.0	13.0	88.5	75.5
750.0	15.5	88.5	73.0



40 cm. Overhang			
mass (g.)	deflection (cm.)	height of end without mass (cm.)	height of end with mass (cm.)
0.0	0.0	89.0	89.0
125.0	0.5	89.0	88.5
250.0	1.0	89.0	88.0
375.0	1.5	89.0	87.5
500.0	1.5	89.0	87.5
625.0	2.0	89.0	87.0
750.0	2.5	89.0	86.5



Conclusion:

The deflection is less when the amount of wood projecting over the edge of the desk is less.

## Day 9: Distribution of the Load in the Supports of a Beam Bridge Activity

### Activity on the Distribution of the Load

Names: \_\_\_\_\_

Date: \_\_\_\_\_

#### About this Activity

In this activity you will learn how the position of a load on a beam bridge affects the force at its supports. You will collect and then record data in both tables and graphs. You will use mathematics to model your activity and to help answer questions about beam bridges. You will learn how to find the line of best fit for your data using a Casio 9850G. A line of best fit minimizes the total distance from all of the points you have plotted to the line.

\*\*\*\*\*

Imagine a board that spans a creek. You wish to sit on the board so that your weight is distributed evenly between both ends. Where would you sit? Why? Most likely, your response to the first question was, “ In the middle.” But, you probably found it a little difficult to explain this response. Following is a modeling activity that shows how mathematics can help explain why you should sit in the middle.

#### Data Collection

1. Make sure you have the following:
  - 1 - Casio CFX-9850G Graphic Calculator
  - 1 - 3" X 1/8" X 18" (7.6cm. X .3 cm. X 45.7 cm ) piece of balsa wood
  - 1 - metric ruler
  - 2 - 200g electronic balances
  - 2 - 225g/25 newton spring scales
  - several mass weights ( approximately 100g each)
  - 2 - pencils or pens to use as supports between balance and balsa wood.
  - 1 - meter stick
  - string, tape, desks or tables
2. Begin your activity by setting up your beam bridge model.

Mark the balsa wood 2.8m. in from one end with a ball point pen. ( This is position “0” and will be placed on one support.) Continue to mark the wood in 4 cm. intervals labeling each position through position 10. ( Position “10” will be placed over the second support.)

3. You need to span two supports with the balsa wood. Place the two supports (pens or pencils) one each in the center of the electronic scales. Make sure that you place position “0” of the balsa wood over one support and position “10” over the other.
4. “Zero” the balances.
5. Place a mass weight at position “0” and record the *Right* and *Left* mass readings in the table below. Continue collecting data by moving the mass from one mark to the next along the balsa wood until you have entries for 11 positions in your table.



6. Once you have recorded your data into the *Right* and *Left* columns in the table, fill in the remaining columns.

**Distribution of the Load Data Table**

Position	Right Balance (g)	Left Balance (g)	Right + Left	Right - Left	Right X Left	Right/ Left
0						
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

## Assignment

Once the table is completed answer the following:

1. There should be a pattern between the numerical entries in the Right Balance and Left Balance Columns, What is it?
2. What does this pattern allow you to conclude about the force and load on beam bridges?
3. Which other columns seem to generate interesting patterns?
4. What do you think these patterns are telling you about the load and force on beam bridges?
5. How can you use your table to predict the location where the load is distributed evenly between both supports?

### Use graphing paper to make a complete graph

Let Right Balance (g) be the independent value or x-axis heading, and let Left Balance (g) be the dependent value or y - axis heading. You will receive points for labeling the axes with the appropriate headings (not x and y). You should give your graph a title. Make sure that you label enough information so that the scale(s) that you use on the axes is/are evident.

Once you have constructed the graph, answer the following:

1. What **type** of **curve** relates the Right Balance reading to the Left Balance Reading?  
Choose a “fit curve”: Line                  Parabola                  Circle

Try to pencil in a “fit curve” onto your graph based on your selection above. Your “fit curve” should be as close to as many of your points as possible. ( It probably won’t go through all of your points.)

Choose any two pairs of Right and Left Balance data from your table and fill the information for the two related points here:

( , ) ( , )

Remember that given any two points on a line that is not vertical, you can calculate the slope of the line by calculating the difference of the “y” values over the difference of the “x” values. You can use these two points to approximate the slope of your line.

2. Calculate the slope of your line here:  
Remember that the y-intercept of a graph occurs when the x coordinate is zero.

3. What is your y- intercept?
  
4. At which position was the mass weight when you collected data that was close to the y - intercept?
  
5. At which position was the mass weight when you collected data that was close to the x- intercept?

## Day 10: Distribution of the Load in the Supports of a Beam Bridge Activity

### Use a graphing Calculator to Graph your data

1. Turn on your graphing calculator.
2. Press **MENU**.
3. Using your arrow keys, highlight **STAT** and press **EXE**.
4. Using your arrow keys, highlight List 1. Press **F6** then **F4** and then **F1** to delete any entries in the column. Delete other lists if necessary by highlighting the List Name and then pressing **F4** and then **F1**.
5. Using your arrow keys, move to position 1 in List 1. Enter your Balance Right data into List 1 pressing **EXE** after each entry. Similarly enter your data for Balance into List 2.
6. Press **F6** until GRPH appears above **F1**, press **F1**.
7. Press **F4** to select your graph and then press **F1** to “turn on” StatGraph1. Make sure StatGraph 2 and StatGraph 3 are set to Draw Off. If these are not the settings, change them using F1 and F2 and the arrow keys.
8. Press **F6** to draw StatGraph1.
9. Press **F1** to investigate the linear regression for the function.

A screen will appear that describes the type of graph. You are using a linear regression. (The graph that you constructed should have resembled a line.) The calculator will list the formula for the “Line of best fit”,  $y = ax + b$ . A line of best fit minimizes the total distance from all of the points you have plotted to the line. Remember that “a” is the slope of the line and “b” is the y intercept.

10. What is the numerical value for “a”? \_\_\_\_\_  
This number should be close to the slope that you calculated .
11. What is the numerical value for “b”? \_\_\_\_\_
12. What is the equation of your line? \_\_\_\_\_

( fill in your numbers for a and b.)

13. What is the numerical value for  $r$ ? \_\_\_\_\_

The  $r$  is the correlation coefficient. This number shows whether a fit is strong or weak. When  $|r| \approx 1$  there is a strong correlation. When  $|r| \approx 0$  there is a weak correlation.

14. What does  $x$  represent on this graph? (This is the independent value.)

\_\_\_\_\_

15. What does  $y$  represent on this graph? (This is the dependent value.)

\_\_\_\_\_

16. What values make sense for  $x$  in the bridge activity?

\_\_\_\_\_

17. Press  for DRAW.

18. Does your line seem to fit your data? \_\_\_\_\_

## **Extension Exercise**

1. Begin your activity by setting up your beam bridge model.  
Using the balsa wood from the previous activity, you need to span two spring scales hung from a meter stick. Use string and tape to support the balsa wood from the scales. One string supports should be placed at position "0" of the balsa wood the support at position "10".
2. "Zero" the scales.
3. Place your mass weight at position "0" and record the *Right* and *Left* mass readings in the table below. Continue collecting data by moving the mass from one mark to the next along the balsa wood until you have entries for 11 positions in your table.
4. Once you have recorded your data into the *Right* and *Left* columns in the table, fill in the remaining columns

### **Distribution of the Suspended Load Data Table**

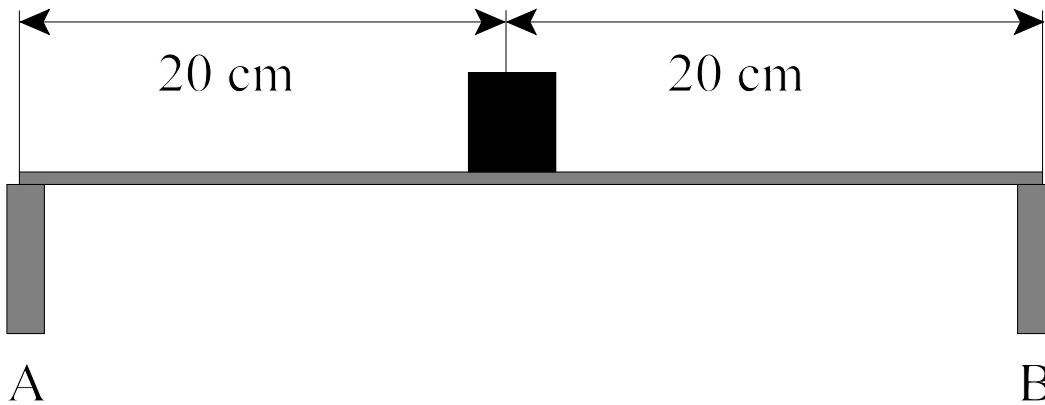
Position	Right Scale (g)	Left Scale (g)	Right + Left	Right - Left
0				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

What generalization can you make about force distribution and supports whether attached above or below a beam bridge?

## Questions to Think About

You and a friend each hold the end of a pole. On the pole is a pail of sand.

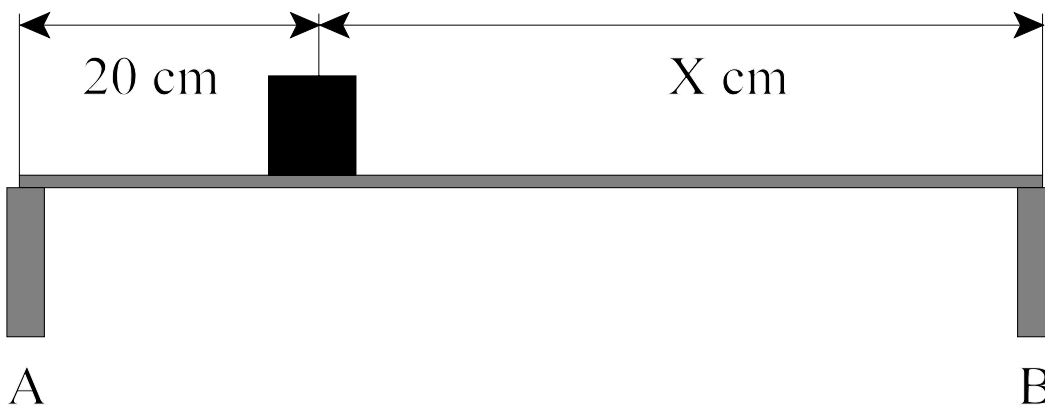
1. Where would you place the pail so that you support less of the load?
2. If the pail is “stuck” in the center of the pole, what could you do to support more of the load?
3. The force exerted by the box on the beam bridge is 15 N.



What is the force supported by end support A ? \_\_\_\_\_

What is the force supported by end support B ? \_\_\_\_\_

4. The force exerted by the box on the beam bridge is 8 N.



The force supported by end support A is 2 N.

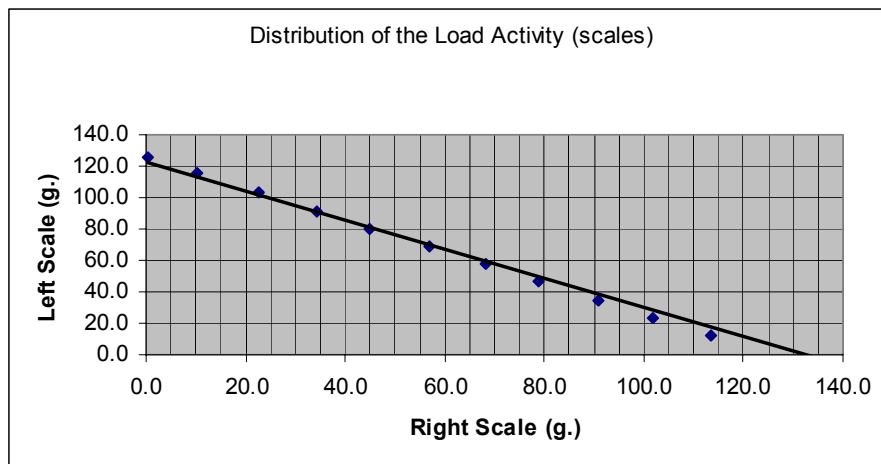
What is the distance X ? \_\_\_\_\_

What is the force supported by end support B ? \_\_\_\_\_

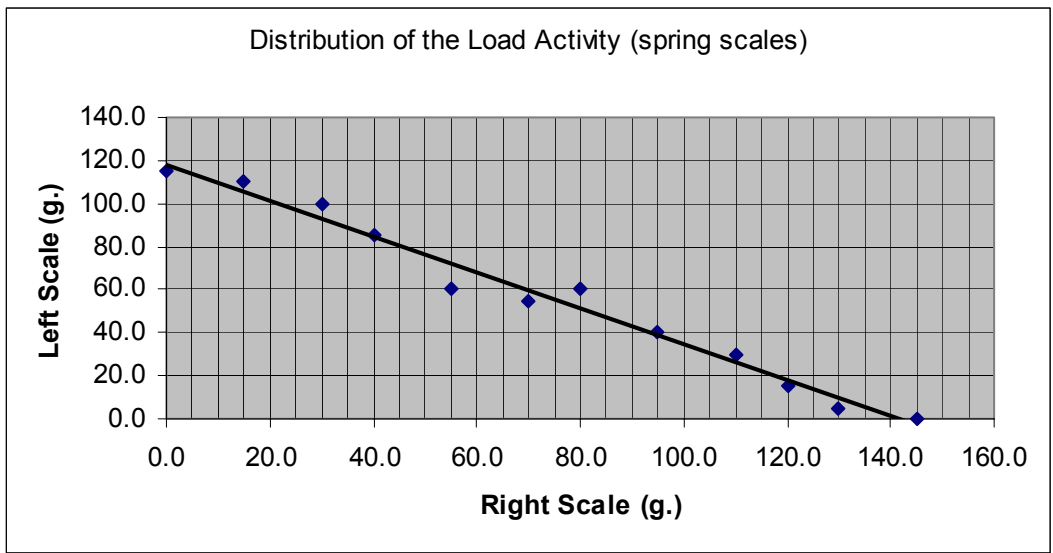
## Day 11 : Distribution of the Load Activity Wrap-up

### Sample Results:

Beam Activity (scales)		
Right Scale (g.)	Left Scale (g.)	Position from right end (cm.)
144.5	0.6	0.0
113.5	11.7	4.0
101.8	23.5	8.0
90.8	34.5	12.0
79.0	46.2	16.0
68.1	57.4	20.0
56.8	68.7	24.0
44.8	80.4	28.0
34.3	91.0	32.0
22.5	103.0	36.0
10.3	115.2	40.0
0.2	125.1	44.0



Beam Activity (spring scales)		
Right Scale (g.)	Left Scale (g.)	Position from right end (cm.)
145.0	0.0	0.0
130.0	5.0	4.0
120.0	15.0	8.0
110.0	30.0	12.0
95.0	40.0	16.0
80.0	60.0	20.0
70.0	55.0	24.0
55.0	60.0	28.0
40.0	85.0	32.0
30.0	100.0	36.0
15.0	110.0	40.0
0.0	115.0	44.0



## Day 12: Student Truss Bridges

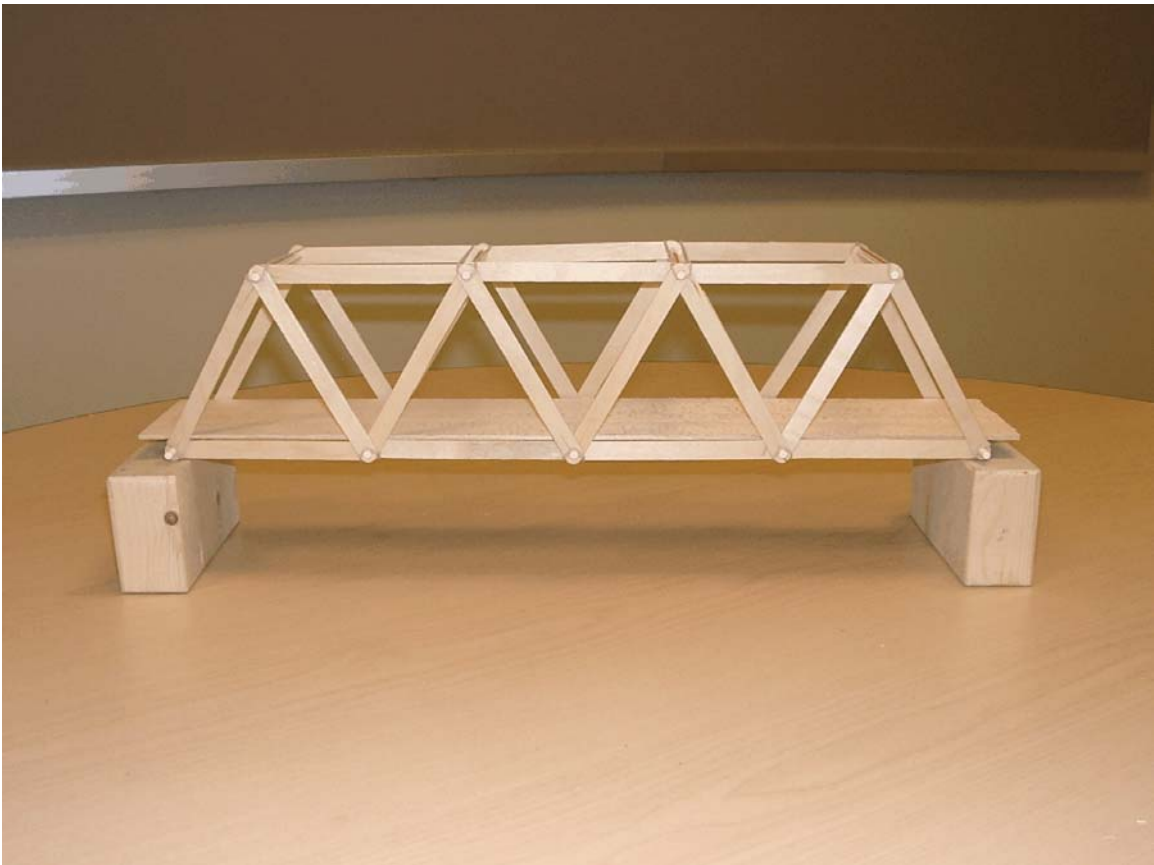
Students will work with a partner and construct a truss bridge.

Students will be given a Ziploc bag with the following contents:

- 30 popsicle sticks (hole drilled at each end)
- 9 lollipop sticks – 4 in.
- 9 straws – 3 in. length
- 9 rubber bands
- 1 3" X 1/8" X 18" (7.6cm. X .3 cm. X 45.7 cm ) piece of balsa wood

Students will see a completed truss bridge and construct one like the model.

When the bridges are completed, students will compare the models.



## Day 13: Deflection of a Bridge Activity

Names: \_\_\_\_\_

Date: \_\_\_\_\_

### About this Activity

In this activity, you will learn how the addition of a truss structure affects the deflection. You will also explore trusses that are attached above and below a beam bridge. You will collect and then record data in tables in order help answer questions about truss bridges

\*\*\*\*\*

### Data Collection

1. Make sure you have the following:
  - 1 - Truss Bridge Model from the Truss Bridge Activity
  - 1 - Metric Ruler
  - Several Mass Weights ( approximately 100g each)
  - 2 - Pencils or Pens to use as supports between support and balsa wood.
  - 2 - Wooden Block Supports
2. Begin your activity by using only the beam bridge model portion of the truss bridge.
3. You need to span two block supports with the balsa wood. Make sure that you place position "0" of the balsa wood over one support and position "10" over the other.
4. Place a mass weight in the center of the beam bridge and record the mass, height without the mass, and deflection in the table below. Continue collecting data by adding enough mass until you have entries for 6 positions in your table.



**Deflection of a Beam Bridge Data Table**

No Truss			
Mass (g)	Height w/o mass (cm.)	Height with mass (cm.)	Deflection (cm.)
0			

5. Repeat the data collection for the truss bridge. Use the same mass entries as those in the first table.



**Deflection of a Truss Bridge Data Table**

Truss			
Mass (g)	Height w/o mass (cm.)	Height with mass (cm.)	Deflection (cm.)
0			

6. Repeat the data collection for the inverted truss bridge. Use the same mass entries as those in the first table.



**Deflection of an Inverted Truss Bridge Data Table**

Inverted Truss			
Mass (g)	Height w/o mass (cm.)	Height with mass (cm.)	Deflection (cm.)
0			

7. Explain how a truss structure affects the deflection of a bridge.
8. Does there seem to be a difference in the deflection between the non-inverted and inverted truss bridge?

## Use a graphing Calculator to Graph your data

1. Turn on your graphing calculator.
2. Press **MENU**.
3. Using your arrow keys, highlight **STAT** and press **EXE**.
4. Using your arrow keys, highlight List 1. Press **F6** then **F4** and then **F1** to delete any entries in the column. Delete other lists if necessary by highlighting the List Name and then pressing **F4** and then **F1**.
5. Using your arrow keys, move to position 1 in List 1. Enter your mass data into List 1 pressing **EXE** after each entry. Similarly enter your data for deflection of a beam bridge into List 2.
6. Press **F6** until GRPH appears above **F1**, press **F1**.
7. Press **F4** to select your graph and then press **F1** to “turn on” StatGraph1. Make sure StatGraph 2 and StatGraph 3 are set to Draw Off. If these are not the settings, change them using F1 and F2 and the arrow keys.
8. Press **F6** to draw StatGraph1.
9. Press **F1** to investigate the linear regression for the function.

A screen will appear that describes the type of graph. You are using a linear regression. (The graph that you constructed should have resembled a line.) The calculator will list the formula for the “Line of best fit”,  $y = ax + b$ . A line of best fit minimizes the total distance from all of the points you have plotted to the line. Remember that “a” is the slope of the line and “b” is the y intercept.

10. What is the numerical value for “a”? \_\_\_\_\_  
This number should be close to the slope that you calculated .
11. What is the numerical value for “b”? \_\_\_\_\_
12. What is the equation of your line? \_\_\_\_\_  
( fill in your numbers for a and b.)
13. What is the numerical value for r? \_\_\_\_\_

The  $r$  is the correlation coefficient. This number shows whether a fit is strong or weak. When  $|r| \approx 1$  there is a strong correlation. When  $|r| \approx 0$  there is a weak correlation.

14. What does  $x$  represent on this graph? (This is the independent value.)

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15. What does  $y$  represent on this graph? (This is the dependent value.)

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16. What values make sense for  $x$  in the bridge activity?

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17. Press  for DRAW.

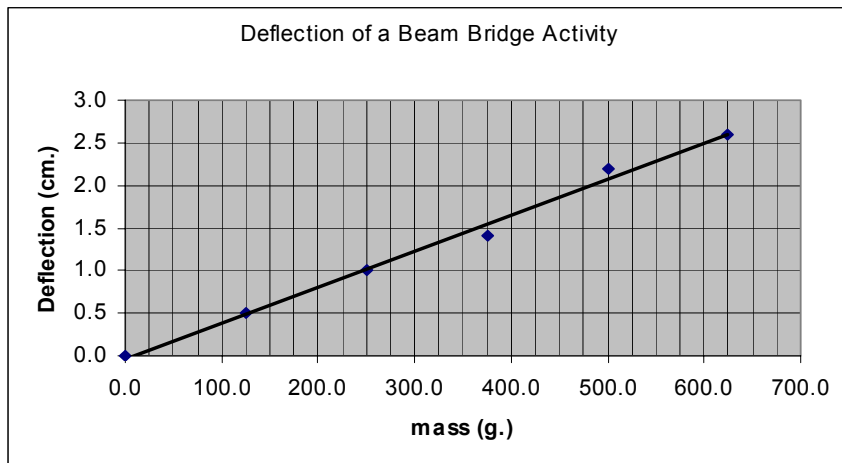
18. Does your line seem to fit your data? \_\_\_\_\_

Repeat the process for the truss bridge data and the inverted truss bridge data.

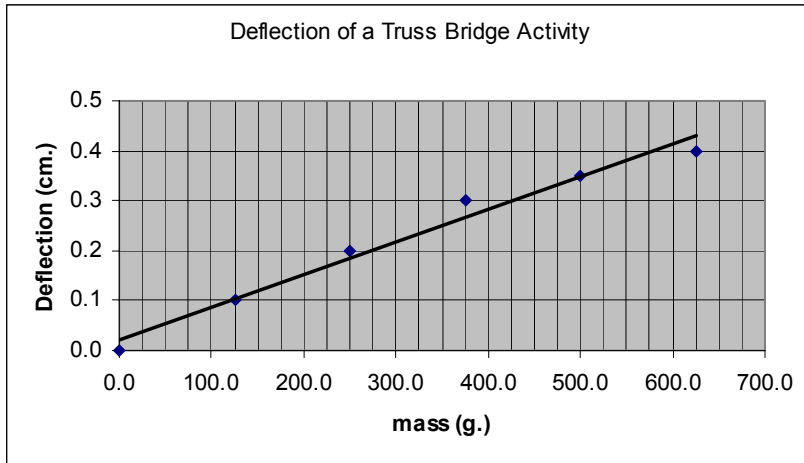
## Day 14 : Deflection of a Bridge Wrap-up

### Sample Results:

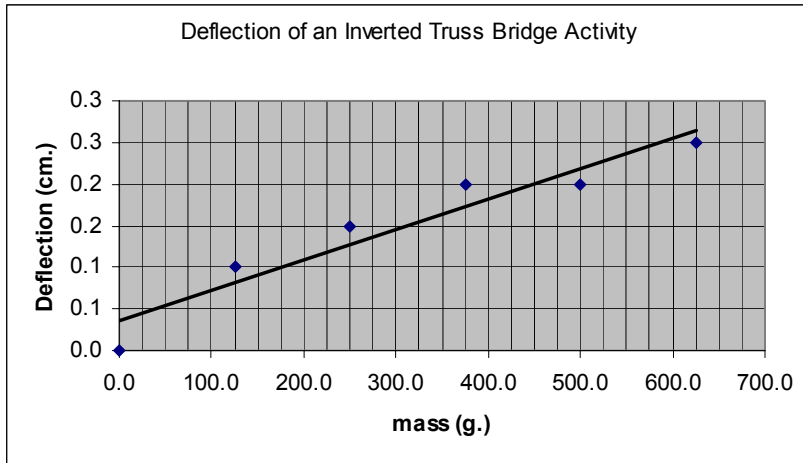
No Truss			
mass (g.)	height with out mass (cm.)	height with mass (cm.)	deflection (cm.)
0.00	6.00	6.00	0.00
125.00	6.00	5.50	0.50
250.00	6.00	5.00	1.00
375.00	6.00	4.60	1.40
500.00	6.00	3.80	2.20
625.00	6.00	3.40	2.60



Truss			
mass (g.)	height with out mass (cm.)	height with mass (cm.)	deflection (cm.)
0.00	12.50	12.50	0.00
125.00	12.50	12.40	0.10
250.00	12.50	12.30	0.20
375.00	12.50	12.20	0.30
500.00	12.50	12.15	0.35
625.00	12.50	12.10	0.40



Inverted Truss			
mass (g.)	height with out mass (cm.)	height with mass (cm.)	deflection (cm.)
0.00	12.70	12.70	0.00
125.00	12.70	12.60	0.10
250.00	12.70	12.55	0.15
375.00	12.70	12.50	0.20
500.00	12.70	12.50	0.20
625.00	12.70	12.45	0.25



The addition of a truss structure to a beam bridge decreases the deflection for the same mass applied to the two bridges.

There is no differences in the deflection of the non-inverted truss and the inverted truss bridges.

## Day 15: Unit Test

### BRIDGES

NAME \_\_\_\_\_ Date \_\_\_\_\_

1. Choose and define 5 words from the list: bridge, span, pier, cantilever, suspension, truss, arch.

a. \_\_\_\_\_

b. \_\_\_\_\_

c. \_\_\_\_\_

d. \_\_\_\_\_

e. \_\_\_\_\_

2. Write a sentence that explains the effect each of these forces has on an object.

a. tension \_\_\_\_\_

b. compression \_\_\_\_\_

c. shearing \_\_\_\_\_

3. Name the 5 types of bridges, give a description of each and sketch each type.

a. \_\_\_\_\_

b. \_\_\_\_\_

c. \_\_\_\_\_

d. \_\_\_\_\_

e. \_\_\_\_\_

SKETCHES:

4. Use the terms: collapse, shear force, and structure in a sentence or two about the Tacoma Narrows Bridge. Why did it fail?

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5. Why is an arch stronger than a simple beam? Explain.

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6. Why is an I-beam stronger than a simple beam? Explain.

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7. What did you learn from the unit on bridges? What activity did you enjoy doing the most and why?

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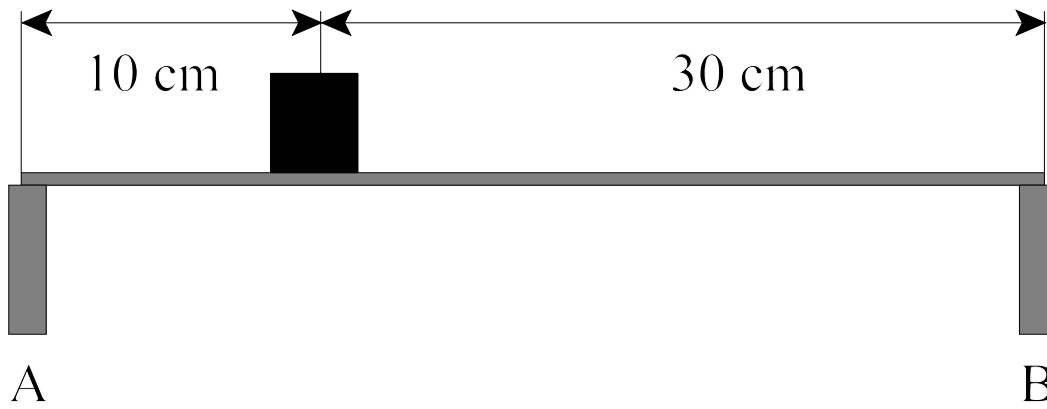
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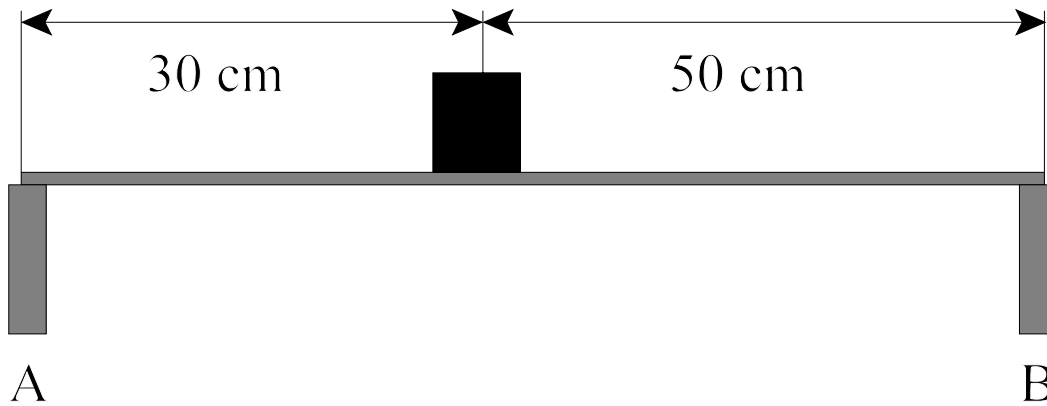
8. The force exerted by the box on the beam bridge is 12 N.



What is the force supported by end support A ? \_\_\_\_\_

What is the force supported by end support B ? \_\_\_\_\_

9. The force supported by end support B is 10 N.



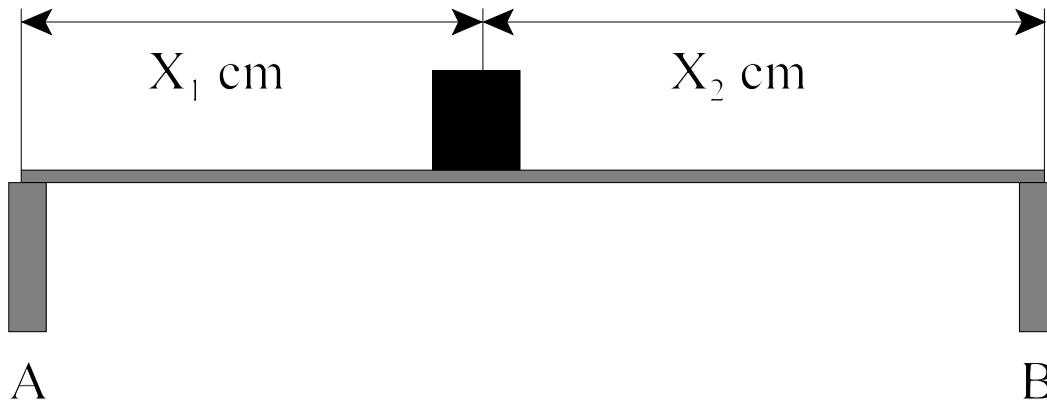
What is the force exerted by the box on the beam bridge ? \_\_\_\_\_

What is the force supported by end support A ? \_\_\_\_\_

Bonus. The force supported by end support A is 10 N.

The force supported by end support B is 25 N.

The total length of the beam bridge is 700 cm.



What is the distance of  $X_1$ ? \_\_\_\_\_

What is the distance of  $X_2$ ? \_\_\_\_\_

## Day 16: Test Rubric

### Unit on Bridges – Grade 7

LEVEL A- This response offers clear and convincing evidence of a clear knowledge of bridges related to tasks.

Characteristics:

- All activities are completed and correct.
- Assigned homework is completed.
- Charts, graphs, mathematical concepts are understood.
- Knowledge of the subject is shown through class discussion/participation.

LEVEL B – This response offers evidence of substantial knowledge of bridges related to tasks.

Characteristics:

- All activities are completed and correct.
- Assigned homework is completed.
- Charts, graphs are completed, mathematical concepts not understood completely.
- Knowledge of the subject is not shown through class discussion/participation.

LEVEL C - This response offers limited and inconsistent evidence of knowledge of bridges related to the tasks.

Characteristics:

- Some activities are completed and correct.
- Assigned homework is complete.
- Charts, graphs are partially completed, mathematical concepts are not understood.
- Knowledge of the subject is not shown through class discussion/participation.

LEVEL D - This response offers little or no evidence of knowledge of bridges related to the tasks.

Characteristics:

- Student does not complete the activities.
- Homework is incomplete.
- Charts, graphs are incomplete, very little knowledge on the mathematical concepts.
- Student has some knowledge on bridges, does not participate in class discussion.

# Proposed Academic Standards for Science, Technology and Mathematics

## Grade 7

### 3.1 Unifying Themes

- B. Describe the use of models as an application of scientific or technological concepts.
  - Identify and describe different types of models and their functions.
  - Apply models to predict specific results and observations.
  - Design a model that illustrates its function.
- C. Identify patterns as repeated processes or recurring elements in science and technology.
  - Identify different forms of patterns and use them to group and classify specific objects.
  - Identify repeating structure patterns.
  - Identify and describe patterns that occur in physical systems (construction).
- D. Explain scale as a way of relating concepts and ideas to one another by some measure
  - Apply various applications of size and dimensions of scale to scientific, mathematical, and technological applications.

### 3.2 Inquiry and Design

- A. Explain and apply scientific and technological knowledge.
  - Answer “What if” questions based on observation, inference or prior knowledge or experience.
- B. Apply process knowledge to make and interpret observations.
  - Measure materials using a variety of scales.
  - Describe relationships by making inferences and predictions.
  - Interpret data, formulate models, design models, and produce solutions.
- E. Know and use the technological design process to solve problems.
  - Define different types of problems.
  - Define all aspects of the problems.
  - Propose the best solution.
  - Design and propose alternative methods to achieve solutions.
  - Apply a solution.

### 3.6 Technology Education

- C. Explain physical technologies of structural design, analysis and engineering, structural production, and design.
  - Use knowledge of material effectiveness to solve specific construction problems (e.g., steel vs. wood bridges).
  - Evaluate a construction activity by specifying task analyses and necessary resources.

### 3.7 Technological Devices

- A. Describe techniques to answer questions and solve problems.

- Identify use of materials, energy and time that meet specific design criteria.

2.3 Measurement and Estimation

- D. Estimate, use and describe measures of weight, mass .
- E. Create and use scale models.

2.4 Mathematical Problem Solving and Communication

- B. Verify and interpret results using numerical tables and equations, charts, graphs and diagrams.
- C. Justify strategies and defend approaches used and conclusions reached.

2.8 Algebra and Functions

- G. Represent relationships with tables or graphs in the coordinate plane.
- H. Locate and identify points on a coordinate system. Graph a linear function from a table or chart.
- I. Generate functions from tables of data and relate data to corresponding graphs and functions.

## Resources

Scienceplus Technology and Society. (1993). Orlando, FL: Holt, Rinehart and Winston and Harcourt Brace Jovanovich.

World Book Millennium 2000 CD

Irene O'Brian Fund