THE WRIGHT CENTER FOR SCIENCE EDUCATION

Innovative Curriculum Series,
Edited by Cathleen Banister-Marx

The Golden Gate Bridge: From U.S. History to Physics

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Gideon Fischer, History

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Longmeadow, MA

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FROM U.S. HISTORY TO PHYSICS

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Courtesy of Pics 4 learning. Photo byGene Bias

INTRODUCTION

GOAL:

Our goal was to create a unit that explores all aspects of the construction of the Golden Gate Bridge from its conception to the present. The unit explores such things as first-hand stories from the men who devoted years of their lives to the bridge, and the science that has made the bridge such an enduring part of the Pacific Coastline. Students will perform research online as well as study articles written when the bridge was built. They will read about the engineers who are seismically retrofitting the bridge, and in a lab setting they will test the strength of cables made from copper and bicycle wire. By the close of the unit, students should understand the interconnectedness of the world that we live in, especially through the eyes of a historian and a physicist.

MATERIALS AND RESOURCES:

Two incredibly useful resources came from the Golden Gate Tourism Office:

http://www.goldengatebridge.org/gift/books.html#60thAnnEdCER

415-923-2342

1. The Golden Gate Bridge: Report of the Chief Engineer by Joseph B. Strauss and Clifford Emmett Paine.

2. Spanning the Gate: The Golden Gate Bridge by Stephen Cassady..

Other resources are:

- Conceptual Physics by Paul G. Hewitt

- Kashima, S & Kitagawa, M.,"The Longest Suspension Bridge," *Scientific American*, December 1997, 88-92.

Recommended videos are:

1. "Super Bridge" video from Nova (PBS), 1997 http://www.pbs.org/wgbh/nova/bridge/

2. "Tacoma Narrows Bridge" video

   Avaliable through The Camera Shop, Tacoma

   http://www.camerashoptacoma.com/narrows.asp#

   253-627-4159

OPENING CLASS EXERCISE

In the first activity of the Golden Gate Bridge curriculum, students will examine their own understanding of the significance of bridges. Students should be placed in groups of three or four and given the following list of questions to answer. After the groups finish answering the questions, reassemble the class for the purpose of having a large group discussion.

BACKGROUND ON THE GOLDEN GATE BRIDGE

An excellent source for background material on the Golden Gate Bridge can be found at: http://www.goldengate.org/. Background reading "Building the Golden Gate Bridge" can be found on the above Web site and would be appropriate for students to read as a homework assignment. If your school has access to the internet, students should be given the opportunity to explore this site as it contains a wealth of information about the Bridge. Students can take a virtual walk across the Golden Gate Bridge, look at different photographs taken during construction and examine various data relating to the Bridge. All materials are easily downloaded and printed off the Web site to be used in class.

DO WE REALLY NEED A BRIDGE WITH SIX LANES OF TRAFFIC?

The Golden Gate Bridge was built for no other purpose than to serve the automobile driver. The ferry system, which had been in use in the San Francisco area since 1850 was severely strained due to the expansion of automobile ownership throughout the 1920s. As city dwellers purchased automobiles, more and more people moved to the suburbs, which in San Francisco meant moving to the other side of the San Francisco Bay. In order to get to the city, suburbanites relied on the ferry system. Traffic at ferry terminals often was backed up for miles and a family on their way to a picnic in the Golden Gate Park or a businessman needing to get to downtown San Francisco could easily waste an entire day waiting for the ferry. This, in and of itself, dictated the need for the building of a bridge across the "Golden Gate."

In order to understand why Americans became such consumers of automobiles in the 1920s and the 1930s, Henry Ford's use of the assembly line should be studied. Other factors such as the increased use of credit when purchasing an automobile was also instrumental in enabling more Americans to purchase automobiles. Most high school history texts have sections covering the history of automobiles. In terms of lessons, the topic of automobiles lends itself to diverse activities such as simulations of an assembly line to rich discussions about the role of automobiles in our society.

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WHAT DO YOU KNOW ABOUT BRIDGES?

In your small group, answer the following questions with as much detail as possible. You can use a separate sheet of paper for your answers.

1. What is the purpose of a bridge?

2. Why are bridges important to study?

3. What materials are used in building bridges?

4. Who benefits when a bridge is built?

5. How would your life be different if the largest bridge near your house was no longer there? Be specific.

6. Who builds bridges? Create a chart listing the different workers needed in order to build a bridge and the jobs they perform.

7. Where does the money needed to build a bridge come from? Be specific.

8. Why do you think some bridges are beautiful, ornate and pleasing to the eye, while others are dull, gray, and without character? Explain your answers.

Teacher Answer Page

THE GOLDEN GATE BRIDGE: FACTS AND FIGURES

We will begin our study of the Golden Gate Bridge online by doing some research about some bridge facts and figures.

After entering the Internet, visit "The Official Website of the Golden Gate Bridge and the Golden Gate Bus and Ferry Transit"

http://www.goldengatebridge.org

Begin by visiting the photos to gain an idea of the relative size of the "Golden Gate" and the bridge that spans it.

Now click on "Research Library"

then on "Construction Data"

then on "Design and Construction Statistics"

1. What is the total length of the bridge, including approaches?

   1.7 miles = 8,981ft = 2,737 m

2. What is the length of the suspension span including the main and side spans?

   1.2 miles = 6450 ft = 1966 m

3. What is the length of the main span portion of the suspended structure?

   4200 ft = 1280 m

4. What is the clearance above mean high water?

   220 ft = 67 m

5. What do you think "the clearance above mean high water" means? Be specific.

   The distance between the bottom of the bridge with live load and the high tide.
   Live load: load with cars and pedestrians.

6. What is the deepest foundation below mean low water?

   110 ft = 34 m

7. What do you think is the purpose for putting the foundation so deep?

    To lower the center of gravity of the Bridge to increase stability.

8. What was the original combined weight of the Bridge, anchorages, and north and south approaches?

    894,500 tons = 811,500,000 kg

9. How many pounds are in one ton?

    2000 lbs = 1 ton

10. What is the combined weight of the Bridge, anchorages, and north and south approaches as of 1986?

    887,000 tons = 804,700,000 kg

11. How many times your weight is the weight of the Bridge (using 1986 figures)?

    887,000 tons x 2000 lb/ton = 1.774×10^9 *lb*
    Then divide by weight in pounds to obtain ratio.

12. What is the difference between the original and reconstructed bridge (in tons and kilograms) and what do you think accounts for the difference?

    7500 = 6,800,000 kg
    Renovations to the bridge have occurred with lighter weight and stronger materials

13. What is the height of each tower above water?

    746 ft = 227m

14. What is the length of one main cable?

    7650 ft = 2,332 m

15. What is the total length of wire used in one main cable?

    80,000 mi = 129,000 km

16. How many wires are in each cable?

    27,572

17. What is the number of strands in each cable?

    61

18. Determine the weight of the two towers, the load on the two towers from the cables and the current weight of the Bridge (not including anchorages and north and south approaches but including suspended structure, towers, piers and fenders, bottom lateral system and othotropic redecking) to estimate the weight that the cables support. (Do not include weight of piers and fenders-you must estimate this and subtract it.)

    Weight of the bridge (not including ...) 419,800 tons = 380,800,000 kg
    Estimated weight of piers and fenders:
    30,000 tons = 27,210,000 kg (answers may vary)
    Suspended weight = weight of bridge-weight of two towers-weight of main cables... - weight of piers and fenders
    Sus weight = 419,800 - 44,000 - 24,500 - 30,000
    Sus weight = 321,300 tons = 291,419,100 kg

19. What do you predict that **dead load** means? What about **live load**? Do you think that the load given above is the dead load or the live load? Why?

    Deadload: load without cars and pedestrians
    Live load: load with cars and pedestrians
    It is the dead load-only the load of the bridge.

VEHICLE CROSSINGS

20. What are the total annual vehicle crossings over the bridge?

    *4*42,465,300 *north and south bound (as of June 2000)*

21. What is the weekday average?

    116,026 north and south bound (as of June 2000)

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2. What is the length of the suspension span including the main and side spans?

3. What is the length of the main span portion of the suspended structure?

4. What is the clearance above mean high water?

5. What do you think "the clearance above mean high water" means? Be specific.

6. What is the deepest foundation below mean low water?

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9. How many pounds are in one ton?

10. What is the combined weight of the Bridge, anchorages, and north and south approaches as of 1986?

11. How many times your weight is the weight of the Bridge (using 1986 figures) ?

12. What is the difference between the original and reconstructed bridge (in tons and kilograms) and what do you think accounts for the difference?

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VEHICLE CROSSINGS

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Teacher Answer Page

THE FERMI SOLUTION:
GOLDEN GATE TRAFFIC LOAD

For homework have students read "The Fermi Solution" by Hans Christian von Baeyer. In it, the life and the unique thought processes of Enrico Fermi are examined.

1. How would you, in your own words, describe the kinds of problems that Fermi strove to solve?

   Fermi enjoyed taking large, complicated problems.

2. How would you, in your own words, describe Fermi's process for solving a problem?

   Fermi would break a problem into pieces, beginning with a piece that he was familiar with. Then he would work piece by piece through the problem until he had arrived at a solution. Usually, this solution was incredibly accurate, despite his string of estimations.

Now, in a group of two to three, solve the following problem using Fermi's method. Write out every part of your thought process.

3. Using the data that you obtained from the internet about vehicle crossings and the dimensions of the Golden Gate Bridge, estimate the live load on the Golden Gate Bridge at any moment in time during the morning rush hour.

   During rush hours, there are 20,905 cars from 6-10 a.m. moving south bound
   So in one of those hours, there are:
   20,905/4 = 5226 cars in one hour, south bound
   The total length of the bridge is 8981
   A car is approximately 15 ft long, so
   8981 ft / (15 ft/car) = 600 cars south bound
   The average weight of one car is 1 ton or 2000 lbs, so the bridge experiences.
   Approximately 600 tons or 1,200,000 lb at any moment during rush hour moving south bound
   The total weight for both directions is 1200 tons or 2,400,000 lb.

   This weight is 894,500/1200 = 745 times less than the bridge's weight.

Name ______________________________ Period ___ Date _______________

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Teacher Answer Page

WHAT IS IT TO BE AN ENGINEER?

Many people believe that engineers are people fluent with equations and computers. So far you have studied the dreams and goals of a different kind of engineer, Joseph Strauss. Now we are going to examine what is iissues related to engineers.

1. In your groups, brainstorm the various aspects of bridge building that an engineer needs to consider. How does the engineer address these issues?

   Designing the bridge
   Obtaining the materials
   Overseeing the construction workers
   Maintaining a safe environment for the workers
   Adhering to a time schedule
   Geological conditions
   Fluid flow of the underlying water (if built over water)
   Air flow about the bridge
   Having a sufficient budget
   Traffic conditions (present and future)
   The beauty of the bridge

   Other answers, and how the engineer will address them, will arise.

2. So far during your study of the Golden Gate Bridge, we have looked at the very successful building of a bridge. Now we will take a look at the unsuccessful building of a bridge.

   (Watch the Tacoma Narrows Bridge video- approximately 10 minutes)

   Now that you have seen the fate of the Tacoma Narrows Bridge, take time with your group to refine your list. Make your revisions in another color so that it will be easy to distinguish what you learned both before and after watching the video.

   Answers will vary. Hopefully students will be more aware of the weather conditions and how they can affect a bridge.

Name ________________________________ Period ___ Date ________________

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SUPER BRIDGE
by NOVA

While watching Nova's episode, "Super Bridge," consider the following questions: Please answer in complete sentences.

1. Where was the Super Bridge constructed?

2. What kind of bridge is the Super Bridge? Why is this bridge well suited to the area in which it was constructed?

3. Who was the Chief Engineer of the Super Bridge? In what ways was he similar to Joseph Strauss? In what ways was he different?

4. Compare and contrast the construction process used on the Golden Gate Bridge and on the Super Bridge. Give examples to support your answers.

Compare and contrast the working conditions for the construction workers on the Golden Gate Bridge and on the Super Bridge. Give examples to support your answers.

What construction “snags” were faced by the workers of each bridge? How were they solved?

Teacher Answer Pages

SUPER BRIDGE
INTERNET ACTIVITY

After watching the "Super Bridge" video from Nova, visit the website

http://www.pbs.org/wgbh/nova/bridge/

To perform all of the activities at the website, you and your partner will need the following materials:

1" x 11" cardboard strip
four textbooks
small sponge
exacto knives
lots of heavy string or yarn
5' section of rope
6' section of rope

Now that you are online, read the opening screen, then go to "Build a Bridge." Survey the four given areas in Step 1, then research each bridge in Step 2.

ARCH BRIDGE
Sketch an arch bridge.

Bridge examples on the following pages are provided courtesy of the website: HowStuffWorks.com

Now visit its site to check its strengths and its weaknesses. How is the weight of an arch bridge supported?

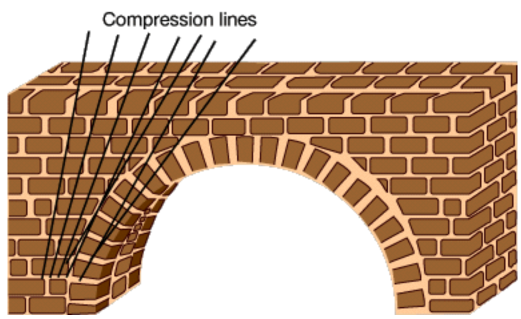
It is carried outward along the curve of the arch to the supports at each end.

What are the supports of an arch bridge called? What do they do?

Abutments--carry the load and keep the ends of the bridge from spreading out

Follow the “Try It!” activity using the cardboard strip and some of your textbooks. What are the differences in the reaction of the arch with and without the books?
Use Newton’s laws to label all the forces on the system with and without the textbooks.

Extra notes about the arch bridge.



http://www.howstuffworks.com/bridge.htm

BEAM BRIDGE

Sketch a beam bridge.

What is compression and how is it caused?

> *Compression is the pushing together of the beam's top edge. It is caused by the live and dead load on the beam.*

What is tension and what is its cause?

> *Tension is the stretching of the bottom edge of the beam. It is caused by the live and dead load on the beam.*

Follow the "Try It!" activity using a small sponge and your textbooks. What happens to the top and the bottom notches of the sponge? Draw a sketch of your beam bridge, labeling the tension, compression, and load.

What is the best material for building beam bridges? Visit the website to see how it is made.

> *Pre-stressed concrete.*

What is the upper limit in length for beam bridges?

> *250 feet*

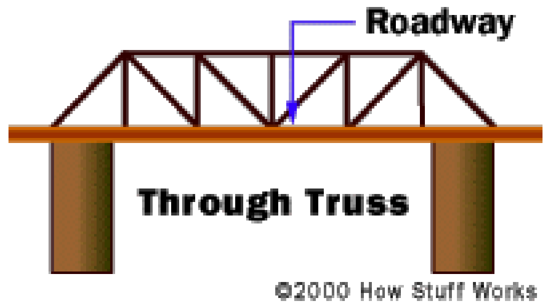
What is the name given to multiple beam bridges?

> *Continuous span*

Extra notes about beam bridges:

SUSPENSION BRIDGES

Sketch a suspension bridge.



What is the greatest advantage of suspension bridges?

They can span the longest distances. (2000-7000 ft)

What is the greatest drawback of suspension bridges?

They are the most expensive.

What carries the majority of the bridge's weight?

By the cables attached to the anchorages.

Perform the "Try It!" activity.

What is the difference in the behavior of the string before and after the anchorages are in place?

The anchorages hold the cable in place, and allow it to support the load from your finger.

What happened to the Tacoma Narrows Bridge?

It broke when a 42 mph wind hit it.

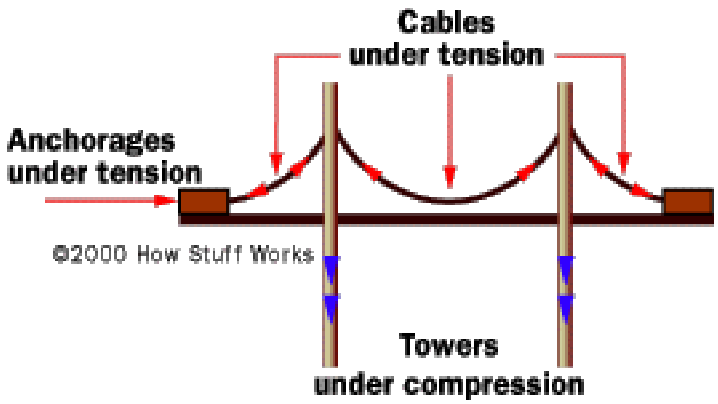
What is the name of the phenomenon which caused its collapse?

Resonance

Additional notes about suspension bridges:

CABLE-STAYED BRIDGE

Sketch a cable-stayed bridge.



How are cable-stayed bridges different than suspension bridges?

Suspension Bridges-cables rise across towers, load transferred to anchorages.
Cable-stayed Bridges--cables attached to towers, towers support load.

What are the kinds of attachment patterns available for cable-stayed bridges? Sketch each.

Perform the "Try It!" activity with your partner.

Where does the compression act on your body?

Additional notes about cable-stayed bridges:

ADDITIONAL QUESTIONS ABOUT BRIDGES

Which is the oldest type of bridge?

Arch

Which ancient empire used this kind of bridge, and where is a famous example of one located?

Roman Empire; Pont du Gard Nimes, France

What kind of bridge is the world's longest bridge, and how long is it? Where is it, and what is it called? What is its drawback?

Beam/continuous span
Louisiana-Lake Ponchartrain Causeway-24 miles
It is not well suited for locations that require unobstructed clearance below.

What kind of bridge is the Sunshine Skyway Bridge? Why has it won awards?

It is a cable-stayed bridge.
The cables in the middle are painted yellow to contrast with the blue of the marine surroundings. There is an unobstructed view of the Tampa Bay.

What is the ideal material for the cables in a suspension bridge? How much can a piece of it support?

Steel - a 0.1 inch thick piece can support over half a ton without breaking.

Read the sections in your text about "natural frequency" and "resonance." What does each mean? What is an example of resonance?

Natural frequency: a frequency at which an elastic object, once energized, will vibrate. Minimum energy is required to continue vibration at that frequency.

Resonance: a phenomenon that occurs when the frequency of forced vibrations on an object matches the object's natural frequency, and a dramatic increase in amplitude results.

Examples of resonance: pumping on a swing, tuning forks with the same frequency that make each other louder.

What is the simplest and most inexpensive form of bridge to build?

Beam bridge

What is another name for a beam bridge?

Girder bridge

Which arch bridge has won many awards? Where is it located, and why has it won these awards?

Natchez Trace Bridge in Franklin, Tennessee
Designed without "spandrels " (vertical supports)
All live load is resting on slightly flattened crowns-aesthetically pleasing

Which kind of bridge matches each site?

5,000 foot span across an ocean bay where huge ships come and go?

Suspension bridge

A 120 foot span across a freeway?

Beam bridge

A 1,000 foot span across a river busy with barge traffic?

Cable-stayed span

A 700 foot span across a deep canyon gorge?

Arch bridge

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Extra notes about beam bridges:

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Sketch a suspension bridge.

What is the greatest advantage of suspension bridges?

What is the greatest drawback of suspension bridges?

What carries the majority of the bridge's weight?

Perform the "Try It!" activity.

What is the difference in the behavior of the string before and after the anchorages are in place?

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What is the name of the phenomenon which caused its collapse?

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5,000 foot span across an ocean bay where huge ships come and go?

A 120 foot span across a freeway?

A 1,000 foot span across a river busy with barge traffic?

A 700 foot span across a deep canyon gorge?

BRIDGE BUILDING
A CONTEST!

Now that we have researched different kinds of bridges, we are going to build our own!

The bridges must fit the following criteria:

1. The only materials that may be used for the bridge are: simple, wooden toothpicks (up to 75 grams) and white glue.

2. The parameters for the bridge are: the roadway must be at least 2 inches wide and the bridge be able to support many times its weight.

Before construction on the bridge begins, each team of four must submit a detailed design for the bridge and a lab report. The report should discuss the kind of bridge that you choose to build, the rationale behind this choice, and the plan that you and your group have for the building process. The design must be an engineering-style schematic diagram that projects the dimensions of your bridge. These must be turned in before construction may begin.

The bridge will be tested with a series of hanging masses. Masses in 50 gram increments will be suspended from the bridge until the structure collapses. The masses will be suspended in a bucket from the bottom of the bridge.

Before the masses are hung from the bridge, the mass of each bridge will be determined. Each bridge will be evaluated by taking the ratio of the maximum mass hung from the bridge (prior to breaking) to the mass of the bridge. The bridge with the greatest ratio will win the competition.

LAB
STRENGTH OF CABLES

PURPOSE: The purpose of this lab is to examine the strength of cables as they increase in number. After gathering data, a graphical analysis will be made of the data on the computer and an equation will be found to represent the strength of the cable.

MATERIALS:

a coil of copper wire
wire cutters
meter stick
various sized masses
three meters of bicycle wire
vertical calipers
electrical tape
Graphical Analysis program

PROCEDURE:

Step One: Work in groups of four to conserve materials. Cut a one-meter length of copper wire. Measure the diameter of the wire with the calipers. Have a partner hold the wire horizontally, and hang masses, beginning with a 50 gram mass, from the wire to determine its strength. Continue to add 50 grain masses until the wire breaks. Now repeat the process for 2 wires, and so on up until you have found the strength of 20 wires grouped together. You may chose to use electrical tape to hold the wires together in two locations. (Be sure that the electrical tape does not come in contact with the loads.)

Record all data in Table One.

Step Two: Begin with a one-meter piece of bicycle wire held horizontally and determine its breaking point. Now, uncoil another one-meter section of the bicycle wire to determine the strength of one of the strands. Uncoil the strand to determine the number of wires in the strand, and the strength of the wires alone, and as they become grouped together (as in Step One.) Record your data in Table Two.

Step Three: Take your data in each table to the computer lab, and create graphs putting the number of strands on the x-axis and the breaking point on the y-axis. Also create graphs that examine the relationship between the diameter of the "cable" and the breaking point. (There should be four graphs total.)

DATA TABLE ONE

COOPER WIRE

TRIAL	# OF STRANDS	DIAMETER	BREAKING POINT
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

DATA TABLE TWO

TRIAL	# OF STRANDS	BICYCLE WIRE DIAMETER	BREAKING POINT
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

Name ________________________________ Period ___ Date ________________

Analysis Questions:

1. What kind of relationship occurs between the number of strands and the strength of the cables? (direct proportion, inverse squared relationship, etc.)

2. Was there a difference between the copper wire and the bicycle wire? What was the difference?

3. What was the relationship between the diameter of the cable and its strength?

4. Using your graphs and the kinds of relationships that you determined in step one, create a formula which describes the strength of the cable for any number of strands.

5. The Golden Gate Bridge used 27,572 strands per cable. How strong would the copper wire be with that many strands? How strong would the bicycle wire be with that number of strands? Show your calculations.

6. Go back to your work with the facts and figures from the beginning of the unit. Do you think that the copper wire or the bicycle wire could support the live and the dead load on the bridge? Why or why not?

PERIODICAL LITERATURE ABOUT THE GOLDEN GATE BRIDGE

The following questions are to be used in conjunction with a sampling of articles published in widely read periodicals between 1933-1937 when the Golden Gate Bridge was being built. They represent a cross section of opinion regarding the construction of the bridge. After each set of questions (follows the magazine article that accompanies it). Teachers can use these documents in a number of ways. For example, the articles could be given as homework and discussed during class. Or, students could read the articles and answer the questions in a small group setting. In any event, the following articles represent a rich source for the deeper understanding of the historical significance of the Golden Gate Bridge and related issues.

Name ______________________________ Period ___ Date ______________

Dereleth, Charles, Jr. "Building San Francisco's Mighty Bridges," *The Literary Diges*t, 116, December 2, 1933, p17.

1 . Why did the author of the article feel that it was necessary to build the Golden Gate and the Oakland-Bay Bridges? Be specific.

2. What are the main differences between the San Francisco-Oakland Bay Bridge and the Golden Gate Bridge?

3. Why would the military be cautious about the building of a bridge at the "Golden Gate" (entrance to the San Francisco Bay)? Do you agree or disagree with this? Why or why not?

4. Describe the quantity of steel and concrete required to build the towers for the Golden Gate Bridge.

Name ________________________________ Period ___ Date ________________

"Golden Gate Bridge to Aid Business: Redwood Empire North of San Francisco will be Connected with Markets to the South. Real Estate Shift Expected. Bridge Celebration Next Week," *Business Week*, May 22, 1937, Pp. 30-32.

1. How will the opening day celebration for the Golden Gate Bridge impact San Francisco Bay area businesses?

2. What does the author of this article believe to be the long range impact of the Golden Gate Bridge on businesses in the San Francisco and Marin County areas? Be specific.

3. How will the Golden Gate Bridge affect where people live? Also, how will it impact the redwood timber industry north of San Francisco?

4. Why does the author believe that the Golden Gate Bridge will be able to withstand an earthquake? Be specific.

Name ___________________________________ Period ___ Date _________________

“San Francisco Bridge,” *Time*, 29, p. 32-36 (See page 40-41).

1. Describe the incident that happened.

2. Based on the information provided, do you think that the deaths of the workers could have been avoided? Why or why not?

San Francisco Bridge

Only one man in the world can tell the story Evan C. Lambert told last week.

He and twelve other men were working up underneath the completed centre span of the new San Francisco-Marin County bridge*. Like wrinkled grey granite, 220 ft. below them ran the swift tidal currents of the Golden Gate. Most of the men were standing on a heavy wooden platform, slung below the rail-girders on steel beams. They were away the boards from beneath the hardened concrete floor of the 4,200 span. Two men were below them picking fallen boards out of the stout hempen safety net that stretched the whole length of the span.

It was about 10 a.m. on Wednesday. On Monday the safety of the platform had been questioned, reinforcing bolts had been put through the brackets which held the four wheels on which the 30-by-60 ft. platform was moved along the rail-girders. On Tuesday, Foreman "slim" Lambert and his crew had worked all day on the platform. A second platform, not yet in use, was suspended at the first tower on the San Francisco side. Unknown to Lambert, a party of State engineers a few minutes before had pronounced that other platform unsafe, were even then walking out on the bridge to reinspect his platform.

It was warm and sunny up there. The workers were joshing each other about the softness of their jobs. Suddenly there was a jar as a corner bracket snapped and tilted the great platform. "It gave a funny shudder and lurched," said Lambert. In an instant another corner came loose. "I felt everything slipping. There was nothing to hang to. So I hollered and jumped into the net. I hit the net just before the staging struck it. The net sagged slowly and then the ropes popped and the net gave way with a sound like thunder. It was like a slow motion picture."

"Going down I don't remember a thing except just before I hit the water with the net. Then I tried to jump. I think I succeeded because I wasn't fouled in the net. I went down in the water, not very deep I think because I came right up again. I saw some timber and grabbed on. Near me I saw feet. I pulled the body up. It was Fred Dummatzen. I looked around. There, tangled in the net was Noel Flowers. I yelled asking could he cut himself out. He just looked at me. God! What a horrified look! Then he went down."

Twenty minutes later, swept almost a mile toward the sea by the outgoing tide, Lambert was rescued by a fishing boat. He still had an arm around Dummatzen. But Dummatzen was dead.

Of the other eleven men, Carpenter Oscar Osberg was picked out of the bay badly injured, the two who had been down in the net were evidently crushed with it fell. Their bodies with seven others were swept out to sea.

Workers up on the bridge watched the crash with horror. "The whole bridge structure shook when the net broke," said one. Peter Anderson, working just above the platform, watched his brother's body spin and twist down and away. Workers raced along the bridge seeking life preservers, found only fire extinguishers. Bridge whistles stopped all work and everyone looked down at the Coast Guard boats circling below.

If there can be a smile in such a tragedy, it came from the l3th man, a spry little Irishman named Tom Casey who felt the staging going, grasped a caster overhead and dangled for seven minutes. "It seemed a hell of a lot longer than that to me!" he said. Workers from above lowered a looped cable through which he inserted his legs, permitting them to hoist him to safety. Not until then did he unclench his teeth from his pipe, let it drop down, down into the Bay.

As four inquiries began, work was indefinitely suspended under the centre span pending restoration of the safety net, more than half of which was torn away in the crash. Costing $82,000, it had saved eleven workers up to last week. Prior to last week only one life had been lost building this bridge. The San Francisco-Oakland Bridge, built without a net, cost 24 lives.

* Scheduled to open May 28.

Name ________________________________ Period ___ Date ________________

Bethlehem Steel Advertisement. *Business Week*, p. 31. May 22, 1937.

Examine the advertisement. What is the Bethlehem Steel Company trying to show or achieve through this advertisement? Is it an effective advertisement? Why or why not? Be specific.

FIRST PERSON ACCOUNTS ABOUT THE GOLDEN GATE BRIDGE

The following first-person narratives address various aspects of "life on the bridge." By reading these accounts, students will enrich their understanding of what it would have been like to be an ordinary worker on the Bridge. The passages cover elements such as their search for employment during a time of economic depression, racial tensions between black and white workers, worker exposure to toxic fumes and the role of the weather and nature in their daily work. It is important for students to learn about these issues as the role of labor in the building of the United States is frequently overlooked. Below are some suggested activities and assignments to be used with these documents.

1. Have students write a paper in which they examine the narratives along with the periodical literature and write a paper in which they

   a) Give general background information about the Golden Gate Bridge.

   b) Discuss the various aspects of the workers lives.

   c) Evaluate the significance of the bridge itself within the context of the Great Depression and the increasing importance of the automobile in the United States.

2. Based on the information taken from the narratives, have students role-play several of the ideas presented in the documents. Furthermore, if it suits the class, students could elaborate and create full-length skits as well.

3. Have students maintain a diary in which they pretend to be workers themselves.

On the Golden Gate Bridge the risk of raising the roadway was heightened by the treachery of the channel itself. Malicious winds were apt to gust and swirl without warning. Sodden fogs could glaze the surface steel to an ice-slick footing. Mindful of these conditions, Strauss and Paine felt compelled anew to consider the issue of safety.

Already they had defied the odds. The neighboring San Francisco-Oakland Bay Bridge, six months from being open, had so far killed twenty-two men, a number considered acceptable by Timothy Reardon, head of the state's Industrial Accident Commission. By contrast, not a single life had been lost on the Golden Gate, owing in part to good luck, but mostly to the foresight of the engineers and their extraordinary precautions.

Since 1933 doctors and nurses were on call at a field hospital near Fort Point. Special diets were prescribed for high steel workers to counteract dizziness. Men with hangovers were required to drink down a cure of sauerkraut juice. To ward off "snowblindness" from the sun reflecting brightly off the Bay, tinted goggles were issued. The Golden Gate was not the first big job to feature hard hats and safety lines as some have claimed. But it was the first to enforce their use with the threat of dismissal. The twenty-second victim of the Bay Bridge neglected to tie himself in, slipped and fell. The Golden Gate allowed no such independence.

Yet as the Bridge was readied to receive its floor there remained a nagging fear that "zero deaths" was too much to ask of fate. Engineers had beaten the one-life-per-million-dollars figure before, but nobody had ever built a major bridge without some fatality. It seemed in the summer of 1936 that the Golden Gate was taunting the law of averages.

In June, Strauss and Paine unveiled probably the most dramatic safety measure in the history of bridge building. They ordered the manufacture of a huge trapeze net to be strung underneath the floor girders. Tied to outriggers extending from the sides of the steel, the 6-inch-square mesh would belly down about 60 feet below where the men were working. The purpose of the net was twofold. Strauss and Paine believed quite obviously that it would save lives. But they also felt that men performing without fear would work faster and more surely, thereby trimming costly days off the length of the job.

On both counts they were correct. The net cost only $130,000, including the price of the erecting frames. That figure was more than made up by the consequent speed of the steelworkers. They raised the floor in a little less than five months, putting up as much as 640 tons a day. And in the course of construction at least nineteen men fell into the net who would have otherwise dropped helpless and screaming toward that hideous death the bridgemen call "falling into the hole."

When it came time to execute the terms, Bethlehem delivered. The north tower had been erected in just under ten months, taking from August of 1933 to May of 1934. With men and techniques refined in the crucible of that experience, Bethlehem finished the southern twin in just 101 working days on the 28th of June, 1935. There was only one incident of note in the building of the San Francisco tower. An earthquake rumbled through the San Andreas Fault in early June, setting the near-finished structure vibrating as violently as if it were some giant tuning fork that had just been struck by a mammoth and malicious rubber hammer.

1. *I was up on the tower when it happened, and I guess there were twelve or fourteen others up there too. I was walking across--I didn't hear nothing, and all of a sudden, I felt like I was tipping off to one side. I sat down and shook my head. I thought I was dizzy or something. This friend of mine, he came along and asked what's the matter. I said, "Jesus, I feel like I'm swaying." He said, "It ain't you, the goddamn tower is s swaying." I got up, and sure enough, this whole structure was swinging like a hammock.*

Guys were going crazy. Some were climbing down through the cells. One guy grabbed some old gloves, put them on, and slid down a derrick cable, took a chance on killing himself--those derrick lines were all greased up, you know. Most of us stayed up there while she was going way over, first to one side, then the other. The elevator that ran up and down outside the tower shaft was about halfway up and was swaying away from the tower then coming back and banging against it. The poor guy inside was throwing up all over himself. Guys on top were throwing up too. After it stopped swaying, we all went down as fast as we could and got first aid for a sick stomach--I think it was a shot of whiskey.

The next day, we went back to work, and we got another one. Those quakes scared the bejesus out of me. I fell into the net on the backspin once, but that was nothing compared to being on top of that tower in an earthquake. And the next day, we was all up there talking about yesterday, and here comes another one. Shit. And you know, the engineers must have known there was going to be a second one, because they had guys from the University of California stationed down at the bottom to measure the sway of the tower. I talked to one guy later; he told me it swayed 30 feet. Thirty feet ain't much 746 feet up, but it's enough to scare the Jesus out of you if you're the one who's up that high. (Frenchy Gales)

2. *Barrett & Hilp was a tough outfit to work for, no question about it. They had a deadline to make, and that was that. They had a saying in those days,"Eight for eight or out the gate," which meant if you couldn't put out eight hours of work for eight hours of pay, you were gone, didn't matter who you were.*

That job separated the sheep from the goats. There was only two colored working for Barrett & Hilp and I was one of them. There was a lot of workers who didn't want to work with a "nigger." Nobody ever said that to my face, mind you, because they knew I'd pound a two by four across the side of their head. But the attitude was there. The company was fair about it, though. Barrett & Hilp knew a man's color didn't have nothing to do with his ability. They laid out the work for you and said,"this is your project." Twenty minutes later, if you were still standing around scratching your head--well, you might get away with it for an hour, but after that you'd be gone.

There was a fence not far from where we worked. On the other side were all the people waiting for somebody to get hurt or screw up so they could have a shot at the job. When the foreman came out of his shack and headed toward the fence, you'd think they were going to mob the gate. He would walk toward them, crook his finger at some guy, and say, "You!" and that was how people got hired. Those new people didn't walk to the job, they ran. And when they got started they worked. One crew could put out twenty-five forms a day, the other crews had better be able to put out as many. If not, the foreman'd hand the laggers their time cards and head for the fence. (William D. Smith)

3. The riveters' jobs often turned unwieldy because of the labyrinthian design of the towers. The 31/2-foot square shaft cells could accommodate only the two riveters, and even that was cramped. The buckerup worked in the next cell over; the heater and his forge were situated on scaffolds hanging outside the tower legs, often 100 to 120 feet away from his gang. He would send rivets to the buckerup through an aluminum hose, a pneumatic tube that snaked up, around, over, down, and around again, until it reached the destination cell. The buckerup would tong the hot rivet from a wire mesh trap, back it into a hole, and press against it with a dollybar. On the other side of the wall, the riveter would stand. Soon as he saw the glowing rivet shoved through the hole, he would jam it with his airjack and vibrate it carefully to a sculptured head.

It was a madhouse in those cells. You had a heater maybe 100 feet away, depending on where you happened to be, with that pneumatic tube coming toward you. You had to make sure the rivets were the right size--they changed with the plate thicknesses of the metal you were working on--and you had to make sure you were sticking it in the right hole. If you screwed up, it would only screw everybody up-the heater, because once you fire up a rivet you can use it only once, and the rest of us, because you would lose time and get behind. So, if you're fighting all that, and you're fighting those coils of airhoses. It was pitch dark in those cells, and the ventilation was poor. You couldn't hear a thing except the noise of the riveting guns and the echoes. And there was many a time the light in your hard hat would go out. (George W Albin)

4. *Within days after the footbridges were finished, Roebling was educating its new men on these intricacies of on-site cable spinning. It wanted only trained mechanics who knew exactly what to expect.*

Roebling had quite a crew of supervisors they brought out from the East-men who really understood the work. And for the rest of us, well, they hired and fired and hired and fired until they shook down to just the kind of crews they wanted.

Before they let any of us get near that spinning operation, they sent us down to Fort Point for a week-long training session. They instructed us on the individual duties we were expected to perform. They only taught us our one job; they wanted us to do one thing to perfection, not a lot of things poorly.

At the end of the week, Mortenson, the foreman, said, "Men, you've been hired for the duration of the job. We know you can put out, or we wouldn't have kept you. If there's any trouble or tie-up while you're working, we have certain crews who know how to fix it. The rest of you don't worry; you don't have to run around trying to find something to do. If you want to sleep, sleep. We know what we want you to do; we know when we want you to do it; we know you can do it. So when there is work to do, we expect it done. When there isn't work, you are on your own."

I had never worked for anybody who had that attitude. Most companies would worry about losing money if everybody wasn't working all day every day. But Roebling had class. They felt their men were individuals, not cogs in a wheel. And they knew how to do a job. (Gerry Conser)

5. *On paper, tower raising is assembly-line smooth, but in fact nothing about the Golden Gate job allowed for complacent routine. The problems began with the weather; at best it was miserable, at worst it was treacherous.*

You couldn't get used to the weather out there; working winters back East was easier on a guy than working summers out here. I started on the Gate Bridge in August. Right away, they gave me a job flashing signals to a crane operator, where , wasn't active physically. I nearly died from the cold. The second day out there, I found some tin and built barrier walls around--so just my head and shoulders stuck out--enough for the operator to see my signals. Later, one of the fellows brought me out an overcoat; it was so heavy I could hardly move my arms to give signals. One thing still sticks in my mind from that job--my feet were always cold.

The weather bothered those guys working the barges, too. One of my old pals had a job hooking on. Well, when those ocean swells come in, it can get pretty rough. The barge would anchor all right, but it would bob up and down, ten, twelve feet, sometimes more. The steel it was carrying weighed some 75 tons apiece, so it was trouble all the way. The guys hooking on would have a double hitch, and two big shackles and pins. They'd get that derrick as near right as they could, and just as it swung by, they'd shove those pins in, slam them home, and hunt for the boondocks. Because--when that barge went down, it left steel dangling in the air; and when it came back up, it would hit the steel slam bang into the pile. My buddy quit the business after that job. His wife was putting too much pressure on him at home, and he decided he didn't want no more of steel work. (Harold McClain)

6. By March of 1934, the ironworkers had built the north tower up to over 600 feet, and the first casualties of the project were beginning to report to the field hospital near the wharf at Fort Point. All the tower metal had been treated so liberally with red lead paint to retard corrosion that the rivet holes were covered by a viscous membrane of the stuff. And when the white hot rivets hit the membrane they touched off violet fumes of lead-tainted smoke that billowed poisonously through the unventilated cells. Workers inside the towers were beginning to turn up debilitated and worse.

There were sixty guys in the hospital at one time. And nobody knew what was causing it. The doctors were diagnosing it as appendicitis--sixty men all coming down with appendicitis at the same time. Finally, it came out that it was lead poisoning. It was awful, that stuff. Guys were losing their hair, their teeth; they were breathing shallow. There was guys who never went back to structural work after getting a dose of lead. (Whitey Pennala)

Treatment followed diagnosis, the victims filtered back to work or were replaced. To immunize against future epidemics, Strauss's and Bethlehem's staffs ordered some progressive changes. Compressed air was forced into the cells for ventilation; riveting gangs were asked to wear filtration masks (something many would pridefully refuse to do); bone phosphate pills were made readily available. Most importantly, from then on the holes in the steel yet to be riveted were reamed painstakingly by hand. Later, when steel for the San Francisco tower was being forged back East, it was treated with iron oxide instead of the red lead.

7. *In the old days, nobody thought much about safety or saving lives, just beating that one man per million score. Nowadays, it's different. You don't have your Pinky Brinkleys or Wino Smittys, or Hook-nose Smittys, or Snot-nose Smittys, or Dirty-neck McCaffertys, or Bad-eye Gerlicks. Those were characters who wouldn't even think of using a ladder or a safety line while they skinned up a ten-foot column that was hundreds of feet in the air. They'd just climb up the sides of the steel by stepping on rows of rivets like they was rungs on a ladder, swing a leg over a girder, hang there, and make their cuts or put in their bolts. (Jay Hollcraft)*

8.

Ironwork had experienced a swashbuckling infancy and adolescence, but by the mid-1930's it was beginning to mature. The era of heedless daring was coming to an end, hastened in part by practices instituted on the Golden Gate. This bridge, the workers were soon to discover, would be one of the first enforcing rigid safety codes. As one of his minor though fervent ambitions, Strauss vowed to pare the "one life per million" formula to a record minimum. "On the Golden Gate Bridge," he said in a 1937 article for The Saturday Evening Post, "we had the idea that we could cheat death by providing every known safety device for workers [including one of the first requirements of hardhats and safety lines]. To the annoyance of the dare-devils who loved to stunt at the end of the cables, far out in space, we fired any man we caught stunting on the job."

Up to that job on the Golden Gate, you were on your own. Nobody cared. If you were fool enough to clown around, you were your own fool. But if they caught you clowning out at the Golden Gate, you were fired. After that, the men themselves began to take a big interest in safety. Why the hell go out and commit suicide when the company was willing to take precautions to save your life?

You want to know how it used to be? One time I was working with a guy on one of the towers of the George Washington Bridge. It was lunch time, and we were sitting up there eating, There was a rig near us; it had one beam sticking out over the roadway. This guy asked me if I could walk the beam. I said I could, but I wasn't going to. He sat there and looked at it for a second, a 20-inch I-beam about 40 feet long, then got up and walked the whole way across it.

What the hell was I going to do, let him show me up? I got up and walked it too. It gets very tricky walking beams when there is no other steel to grab on to if you start to fall. It can get real lonesome. But I walked it just as fast and as sure as that other guy. The old captain, he was watching us from down on deck, and he got madder'n hell. He chewed us out good when he caught up to us. But that's all he did. We'd have tried that on the Golden Gate and nobody would have bothered to talk about it. We'd have been fired on the spot. (Harold McClain)

9. *There were times during the Depression that my wife and I wouldn't eat just so the baby would have enough food. I remember some days I walked along Market Street from the Ferry Building to Van Ness Avenue looking for a job. It might take a half day to walk up one side of the street and a half day to walk down the other. I'd knock on the door of every business on that goddamned street, and, like as not, I'd get turned down at every one of them.*

Then the Bridge came along, and some of us found work. I remember going out there one day--they hired and fired on the spot--and talking to one of the Pacific Bridge foremen, Blackie Silver. I said to him, "How about a job?" He looked me over for a second, then asked, "You ever worked high?" I said, "Mister, I'm *looking for a job: It don't matter where or what. I need work." So he pointed out toward the roadway--this was when they had just finished putting up the steel across the Gate, and there was nothing out there but girders. He said, "See those panels out there?" I said, "Yeah, I see them." He said, "Go get 'em."*

His words hit me right in the pit of my stomach. The panels were like 100 feet out toward the middle. That meant walking along those girders with nothing to hold on to, balancing myself on 8-inch I-beams with only net and water underneath. The thought of walking the flanges scared the hell out of me. But I did it. I learned quick that when the wind was blowing, which was all the time out there, you had to carry lumber on the side away from it. If you didn't, it could get hold of you and blow you right into the drink.

I don't know how, but I managed to make it back all in one piece. I must have been whiter than a sheet. Blackie looked at me a while. He said, "I see that you're scared." I said, "You're goddamned right I'm scared." He hesitated for a second. "Well at least you got guts enough to go out there ... Okay, you can go to work." (Pete Williamson)

Cassady, Stephen. Spanning The Gate: The Golden Gate Bridge. pp. 70-71. Squarebooks, Santa Rosa, California; 1986.

Teacher pages:

EARTHQUAKES
INTERNET RESEARCH

Once you have logged on, please visit

http://quake.seismo.unr.edu/htdocs/abouteq.html

http://quake.wr.usgs.gov

In your groups, answer the following questions:

1. What is the primary cause of earthquakes?

   Earthquakes occur along fault lines, where the Earth's plates meet.

[Editor's Note: As per USGS, an earthquake is caused by a sudden slip on a fault. Stresses in the earth's outer layer push the sides of the fault together. Stress builds up and the rocks slips suddenly, releasing energy in waves that travel through the earth's crust and cause the shaking that we feel during an earthquake. An EQ occurs when plates grind and scrape against each other.]

2. What is a tectonic plate?

   One of the pieces of the Earth's crust that joins together like a puzzle piece to create what we know as the crust.

3. How are the boundaries of the plates located?

   By studying and mapping earthquakes, faults and volcanoes.

4. What are the three main plate tectonic environments, what do they do to the plates, and what is a diagram that would represent each?

   Extensional-would pull apart the plates
   Compressional-would push the plates together
   Transform-would drag the plates along each other

5. What is seismic deformation?

   Seismic deformation comes in two forms:
   Static deformation is the permanent displacement of the ground due to the event.
   Dynamic deformation occurs in waves similar to sound waves called seismic waves.

6. What are seismic waves?

   Seismic waves are the dynamic deformation of the ground due to an earthquake. They make up 10% of the energy that comes from earthquakes. There are two forms seismic waves-P waves and S waves.

7. What are compressional waves? Draw a picture to illustrate your explanation.

Compressional waves are P waves. They shake the ground in the direction that they are traveling and they travel the fastest- 1. 5 to 8 kilometers per second

8. What are shear waves? Draw a picture to illustrate your explanation.

Shear waves are S waves. They shake perpendicularly (or transverse) to the direction of propagation. They travel at 60% to 70% the speed of P waves.

9. From your text, what is the definition of a wave?

A wave is a wiggle in space and time.

10. Do waves carry energy?

YES!

11. What is the Law of Conservation of Energy?

Energy cannot be created or destroyed. It can be transformed from one form into another, but the total amount of energy never changes.

12. If energy cannot be created or destroyed, then where does the energy from the S and the P waves of the earthquake go?

The energy of the earthquakes goes into the destruction of the buildings and the land that borders the fault lines.

Name ________________________________ Period ___ Date _______________

EARTHQUAKES
INTERNET RESEARCH

Once you have logged on, please visit

http://quake.seismo.unr.edu/htdocs/abouteq.html

http://quake.wr.usgs.gov

In your groups, answer the following questions:

1. What is the primary cause of earthquakes?

2. What is a tectonic plate?

3. How are the boundaries of the plates located?

4. What are the three main plate tectonic environments, what do they do to the plates, and what is a diagram that would represent each?

5. What is seismic deformation?

6. What are seismic waves?

7. What are compressional waves? Draw a picture to illustrate your explanation.

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9. From your text, what is the definition of a wave?

10. Do waves carry energy?

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12. If energy cannot be created or destroyed, then where does the energy from the S and the P waves of the earthquake go?

Name ________________________________ Period ___ Date _______________

THE SEISMIC RETROFIT OF THE GOLDEN GATE BRIDGE

Now that you have read about the Akashi Kaikyo Bridge in Japan, and have researched earthquakes, work in small groups to brainstorm methods of seismically retrofitting the Golden Gate Bridge. Address the following questions in your discussion, and appoint a secretary in the group to keep track of everything that is mentioned and debated.

1. What does it mean to seismically retrofit a structure?

2. What measures were taken with the Akashi Kaikyo Bridge's construction to make it"earthquake safe?

3. Is retrofitting the Golden Gate Bridge an appropriate way to spend tax dollars and the money that is generated from its tolls?

4. What magnitude of earthquake should we prepare for?

5. Specifically, what should be done?

Once your group has reached consensus as to what should be done to the bridge, please visit

http://www.goldengate.org/

and read the information given under "Seismic Retrofit Information7' and "News Releases." Take notes individually as to the measures that are being taken to retrofit the bridge.

SEISMIC RETROFIT-PHASE TWO

In your original groups, armed with your notes from your debate and from your internet research, compose individual business letters that are addressed to the Seismic Retrofit Committee for the Golden Gate Bridge. In the letter, you should propose either another aspect of the Bridge that should be retrofitted, and how it should be done, or how the Bridge could better generate revenue for the Retrofit project.

Once you have generated a rough draft of your letter, use the other members of your group to peer edit the letter. Each person should peer-edit each letter in the group.

A final draft of the letter, typed in correct business letter format is due two days after the peer-editing.

CLOSING ACTIVITY
GUEST SPEAKER

To close the unit on the Golden Gate Bridge, we suggest that you bring a guest speaker into your classroom, What can be more powerful is to bring in a panel of speakers, including an engineer who designs bridges, a worker who constructs bridges, a congressperson who raises revenue for bridges, and a commuter who uses a bridge on a daily basis.

Should your classrooms be near the Golden Gate Bridge, then you are in an excellent position to provide a relevant experience for your classrooms. Should you live near the Super Bridge, then you could contact some of the people from the Nova special. However, every community is impacted by bridges, and we are confident that a panel or single speaker can be found.

We advise that you work with your students in advance and have them prepare questions for the speakers to aid in the interchange of dialogue.

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