raft resource area for teaching
www.raft.net

Curriculum topics:

- Forces
- Engineering
- Design

Subject:
Physical Science

Grade range: 4 – 12

LEONARDO'S ARCHED BRIDGE

Build a robust bridge without glue, nails, screws, or rope!

Make a self-supporting bridge designed by Leonardo da Vinci. Be amazed by the ingenious simplicity of his creation! Use Leonardo's idea to inspire a student design challenge.

Who we are:

Resource Area for Teaching (RAFT) helps educators transform the learning experience through affordable "hands-on" activities that engage students and inspire the joy and discovery of learning.

For more ideas and to see RAFT Locations

www.raft.net/visit-raft-locations

Materials required

- 18 Bridge Beams (paint sticks) per bridge
- Optional: weights and scale(s)

Design Challenge Introduction

Before going to the "How to build it" section, challenge students to use their ingenuity to see if they can create a bridge using 18 sticks and nothing else - no tape, no glue, no nails. Don't show them any pictures or give them any hints.

At first they will think it is impossible. Encourage them to play with the sticks and see if any ideas come to mind. Eventually, one or more students will get the idea of weaving some sticks together. As soon as that happens, focus the attention of the other students on that idea. Soon, everyone will be trying to weave sticks together. At this moment, the students are experiencing the same creative "breakthrough" that Leonardo experienced!

Now show them pictures of Leonardo's bridge. Some students will be able to build their own version with no other instructions. For everyone else, a step-by-step guide is provided below.

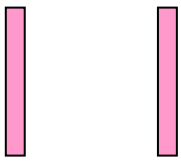
For extra help, see the Leonardo's Bridge

VIDEO: http://www.raft.net/raft-idea?isid=580
PHOTO GALLERY: http://www.raft.net/raft-idea?isid=580

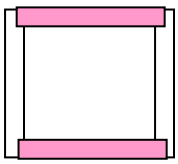
How to build it

In these drawings, the beams being added in each step are shown in PINK:

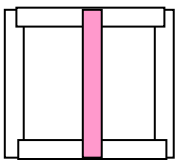
1. On a flat surface, place two beams parallel to each other as shown at right.



2. Place two more beams on top the first two to form a square.

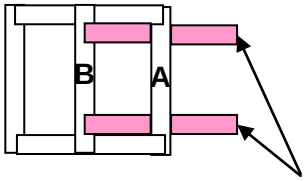


3. Put the next beam in the middle of the square (on top of the others).



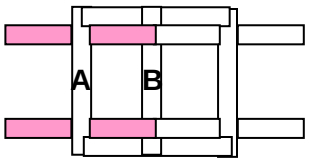
4. Use your left hand to gently lift Beam (A) a few inches off the table. Be careful not to shift the other beams.

   Use your right hand to carefully slide a new beam under (A) and over (B). Do the same thing with a second beam, as shown at right.

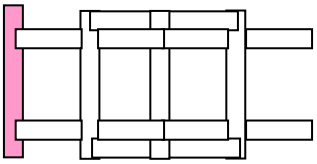


Under A, over B

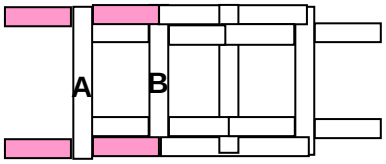
5 Now repeat this process by sliding two beams under (A) and over (B).



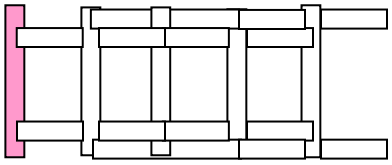
6 To make your bridge bigger, add another cross beam as shown.



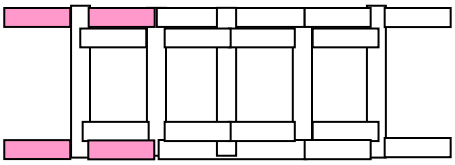
7 Slide two beams under (A) and over (B).



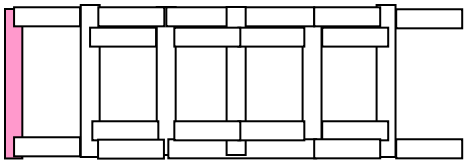
8 Add another cross beam as shown.



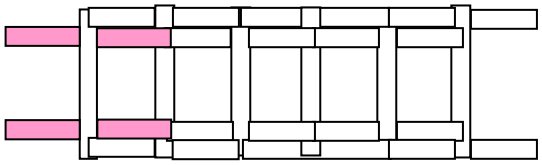
9 Slide two beams under (A) and over (B).



10 Add another cross beam as shown.



11 Slide in the final two beams. You are **done**!



To do and notice

1 Once the bridge is completed, test it by pressing down with one or two fingers near the center of the span. Look for any shaky connections and make sure the pieces are accurately aligned.

2 Now place a suitable weight on top of the bridge. Start with about ½ kg (1lb) or so. Use a ruler to note how far the bridge deflects under the weight. Be careful not to overload the bridge and risk breaking the beams.

Calculate the efficiency by dividing the weight of the supported load by the weight of the bridge.

$$\textbf{Efficiency} = \frac{\text{Weight of the supported load}}{\text{Weight of the bridge}}$$

3 If the students were provided with step-by-step instructions to do the project, have the students dismantle the finished bridges and rebuild the bridges without instructions.

Curriculum Standards:

Forces & Motion (Next Generation Science Standards: Middle School, Physical Science 2-2, High School, Physical Science 2-1)

Gravity (Next Generation Science Standards: Grade 5, Physical Science 2-1)

Compare Multiple solutions (Next Generation Science Standards: Grades 3-5, Engineering Design 1-2, Middle School, Engineering Design, 1-2 & 1-4)

Test variables & Design criteria (Next Generation Science Standards: Engineering Design, Grades 3-5, 1-1 & 1-3; High School, 1-3)

Break complex real-world problem into smaller problems (Next Generation Science Standards: Engineering Design, High School, 1-2)

Science & Engineering Practices (Next Generation Science Standards: Grades 4-12)

Additional standards at: http://www.raft.net/raft-idea?isid=580

The science behind the activity

Modern bridges are built with high-strength materials and carefully-selected fasteners. Design considerations include the weight of the bridge and the load it carries as well as stresses caused by wind and earthquakes. Bridge components are subject to **tension** (pulling), **compression** (pushing), **torsion** (twisting), and **shear** (forces that act at an angle).

Leonardo's arched bridge is brilliant in that the design is self-supporting, requiring no fasteners. Leonardo envisioned using nothing but large logs to build his bridge. The bridge's own weight holds it together. As weight is added to the bridge, its structural elements are forced more tightly together, making it even stronger!

Learn more

- Challenge students to design & build bridges using other materials –see RAFT Idea Sheet ***Bridging the Gap***.
- Create a Design Challenge with this activity. See the RAFT Idea Sheet ***Designing Design Challenges*** for ideas.

Related activities::
For more direct demonstrations of inertia, see RAFT Idea Sheets:

Hole in One -
http://www.raft.net/ideas/Bridging the Gap.pdf
Old Tablecloth Trick -
http://www.raft.net/ideas/Old Tablecloth Trick.pdf

For other interesting activities related to forces, see RAFT Idea Sheets:

Bridging the Gap -
http://www.raft.net/ideas/Bridging the Gap.pdf
Buzz Off -
http://www.raft.net/ideas/Buzz Off.pdf
Gravity Defying Frog -
http://www.raft.net/ideas/Gravity Defying Frog.pdf
Hovercraft -
http://www.raft.net/ideas/Bridging the Gap.pdf
Kimoto Life Capsule -
http://www.raft.net/ideas/Kimoto Life Capsule.pdf
Lunch Plate Launch Pad -
http://www.raft.net/ideas/Lunch Plate Launch Pad.pdf
Roller Racer -
http://www.raft.net/ideas/Roller Racer.pdf

Resources

Visit http://www.raft.net/raft-idea?isid=580 for photos, "how-to" video demos, and more ideas!

See these websites for more information:

- **Design ideas and details** –
  http://www.garrettsbridges.com/
  http://www.jhu.edu/~virtlab/bridge/truss.htm

Leonardo’s Bridge