Telescope Technology

Grades 6-12

McDonald Observatory's 2.7-meter Harlan J. Smith Telescope and Hobby-Eberly Telescope both use mirrors to reflect light and bring it to a focus. (If you did the suggested pre-visit Reflection Activity, you have already explored this aspect. If you haven't done it yet, you might try it before moving forward in your investigation of telescopes.) Although they are different in structure and range of motion, both telescopes depend on more than the "law of reflection" to operate. A telescope could be considered as a laboratory for examining various laws of motion in physics. The three sets of activities on this page, and the in-depth "Mighty Tetrahedron" activity that follows, will help you explore some mechanical properties of telescopes.

2.7-meter Harlan J. Smith Telescope: Counterweight

The large counterweight on the opposite side of the rotation axis of the telescope from the tube helps keep the telescope and its attached instruments in balance.

- Activity one: Balance a pencil horizontally on the end of your finger. If you attach a piece of clay or Play Dough to the end near the eraser, will you move your finger towards or away from the Play Dough so that it continues to balance? Now, try it. Explain why you moved your finger.
- Activity two: Now try to balance a ruler. Use a scale to measure the amount of Play Dough you plan to add. Can you predict where to move your finger? Try it, and then predict where your finger must be for two and three times the amount of Play Dough. Test your prediction. Write down a rule for balancing weights.

Hobby-Eberly Telescope: Main Truss

The 91 one-meter mirrors in the HET are held in place by a truss system of triangles. Explore why engineers chose triangles rather than rectangles for the truss system.

- Activity one: Make a truss from craft-sticks to hold the weight of your textbook. Which shape needs fewer parts to hold a weight: a cube made of six squares or a tetrahedron made of four triangles? Which shape do you expect will hold more weight? See the following activity named "The Mighty Tetrahedron."
- Activity two: Test how much weight your structure can hold. Does adding cross supports of string help your structure to hold more weight? Explain.

Hobby-Eberly Telescope: Motion System

The HET does not move while it is taking data, but it can move between observations so that another part of the sky can be viewed. The telescope is lifted up by air bearings and then rotated by small motors. The escaping air from the bottom of the bearings allows the entire telescope to float (as in the hovercraft activity referenced below.) Try these activities to learn how air can lift heavy objects.

- Activity one: Using strong tape, but *not* masking tape or duct tape, seal a large plastic garbage bag (without inflating it). Stronger bags are better than thinner bags. Place the bag flat on the floor, surrounded by students. Put a large object on top of the bag. Ask the students if they think air could lift that object. Pass straws around to the students. Have the students puncture the bag with their straws and blow air into the bag. (It may be necessary to put tape around the holes.) As the bag inflates, the object will rise.
- Activity two: Have a competition between groups to see what changes might allow the bag to lift more weight, or to lift the weight higher.

Mighty Tetrahedron

Grades 6-12

The triangle and tetrahedron are rigid structures that can be found in a variety of buildings, bridges, airports, and stadiums. The Hobby-Eberly Telescope (HET) primary mirror truss is constructed of "tinker toy" bars and sockets that form a huge hexagon of interconnected tetrahedrons. The truss must hold its shape to support its own weight plus the 91 mirror segments (each weighs 113.4 kg or 250 pounds, for a total of 10,341 kg or 22,798 pounds) that make up HET's primary mirror. Without this stable platform, the mirror segments would quickly stray from their precise alignment, resulting in blurry images and lost light. Students will explore and compare the properties of triangles and tetrahedrons verses squares and cubes. They will discover that triangles and tetrahedrons are much more rigid than squares or cubes.

Materials

- 9 hobby-type "Popsicle" craft sticks per student
- stapler
- 100 straight soda straws or wooden skewers
- modeling clay
- 2 sets of identical classroom objects to load the structures

2-D Exploration

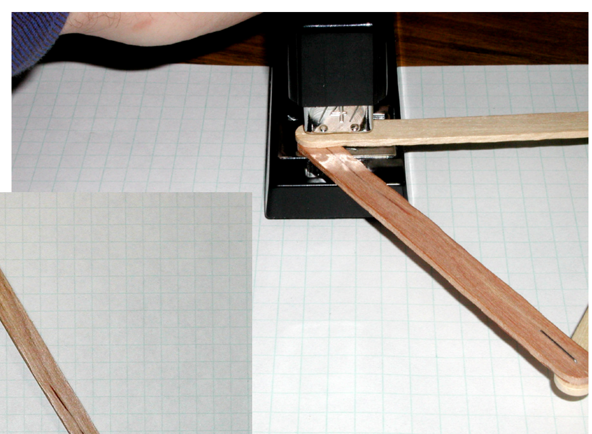
Goal: Understand why triangles are more rigid than squares.
Objectives: Students will…

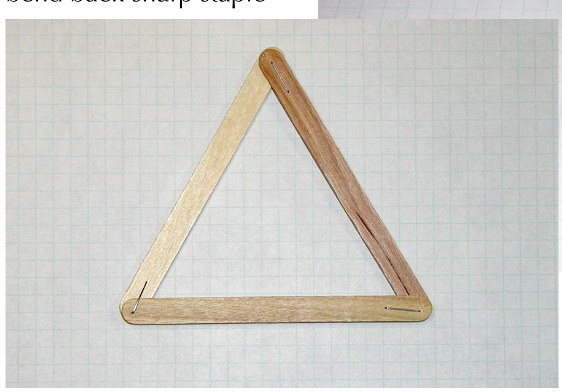
1. Build a triangle and square using the same sorts of materials.
2. Stress the shapes by pushing and pulling to explore their structural properties.
3. Explain "rigid" in terms of their experiment.
4. Determine which shape is best for building structures that depend on rigidity, like the HET truss or a bridge.

Building the shapes:
Pass out 9 sticks to each student. They will use 8 to construct the shapes, and will use the extra stick to safely bend back sharp staple ends.

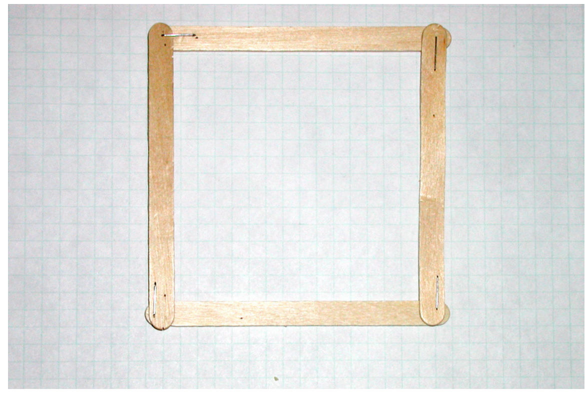
<u>The Triangle:</u>
Staple the rounded ends of the craft sticks together.

- Position the stapler and sticks so that only one stable prong joins the two sticks.
- Push firmly but slowly down on the stapler.
- Gently flip the triangle over to bend back sharp staple prongs.





The Square:
Staple four sticks together to make the square. Use the same procedure as making the triangle.

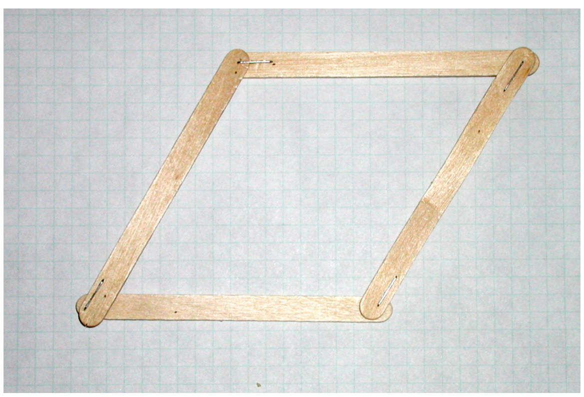


Experiment:
Which shape can you "squish"?

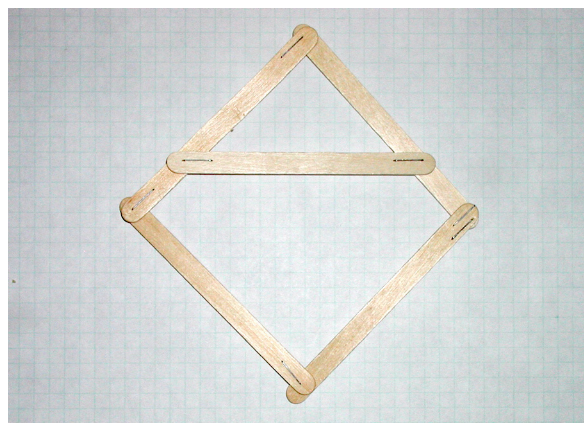
- Try the triangle — does it squish or hold its shape?
- What about the square?

Try pushing / pulling at different places on the triangle and square.

- Under what kinds of stress does the square hold its shape, or squish?
- What does the square need to hold its shape under stress?



"Squished" square



Square with a brace

The square needs a brace to hold its shape under stress. Staple the eighth stick to the square.
What shape does the brace form with the sides of the square? (Triangle)
How **rigid** is the square + brace structure now? Compare it to the triangle.
Based on your experiment:

- How would you define **rigid?**
- Which shape would you pick as a basic structural element for a bridge, or the HET truss?

3-D Exploration

Goal: extend student's 2-D experience into 3-D based on their experiments to understand why the HET truss is composed of tetrahedrons.

Objectives:

1. Build a tetrahedron and a cube with straws and modeling clay.
2. State a hypothesis: what outcome do you expect and why?
3. Design and implement an experiment to test which structure can support the greatest load.
4. Record experiment data.
5. Explain, based on experimental evidence, why the HET truss is made out of tetrahedrons instead of cubes.

Build the Cube with your imagination Describe a cube in terms of squares: • A three-dimensional object with 6 sides or faces. • Each side is a square. How many straws will you need? (12) How many pieces of clay will you need? (8)	*Build the Cube with straws and modeling clay* Begin by making 8 clay balls and laying out 12 straws. Make a square base (4 straws + four balls). Add vertical sides, with a ball on top of each vertical (4 straws + four balls). Connect the verticals to horizontal straws (4 straws).
Build the Tetrahedron with your imagination Describe a tetrahedron in terms of triangles: • A three-dimensional object with 4 sides or faces. • Each side is a triangle. How many straws will you need? (6) How many pieces of clay will you need? (4)	*Build the Tetrahedron with straws and modeling clay* Begin by making 4 clay balls and laying out 6 straws. Make a triangle base (3 straws + 3 balls). Stick one straw vertically into each ball (3 straws). With the last ball, bind the three free straw ends together (1 ball).

Experiment:

Squish Test:

What do you think will happen if you stress the cube and tetrahedron?
Try "squishing" the structures with pushes and pulls (forces) using your fingers.
Cube vs. Tetrahedron:

- Under what forces is the cube or tetrahedron rigid?
- What forces "squish" the cube or tetrahedron?

Load Test:

Connect the four cubes together to form a single square-base structure. Do the same with the six tetrahedrons to form a hexagon-base structure.
Form a hypothesis: which structure will support the most weight and why?
Test the structures individually, or side by side:

1. Place a Plexiglas sheet over the top of the structure.
2. Incrementally load each structure until it collapses:
   - Slowly and simultaneously load up each structure by placing one item per trial on the Plexiglas sheet.
   - Record the load and make notes of structural changes for each trial.

Conclusions

After both structures collapse, explain why you think each structure failed. Recommend improvements to make the structure more rigid for a new experiment. Based on your experiments and observations, why do you think the HET truss is made of tetrahedrons instead of cubes?