Ever *fly* a TETRAHEDRON?

by Kenneth King

Few things capture the spirit of spring like flying a kite. Watching a kite dance and sail across a cloud-spotted sky is not only a visually appealing experience, it also provides a foundation for studies in science and mathematics.

The science of kites

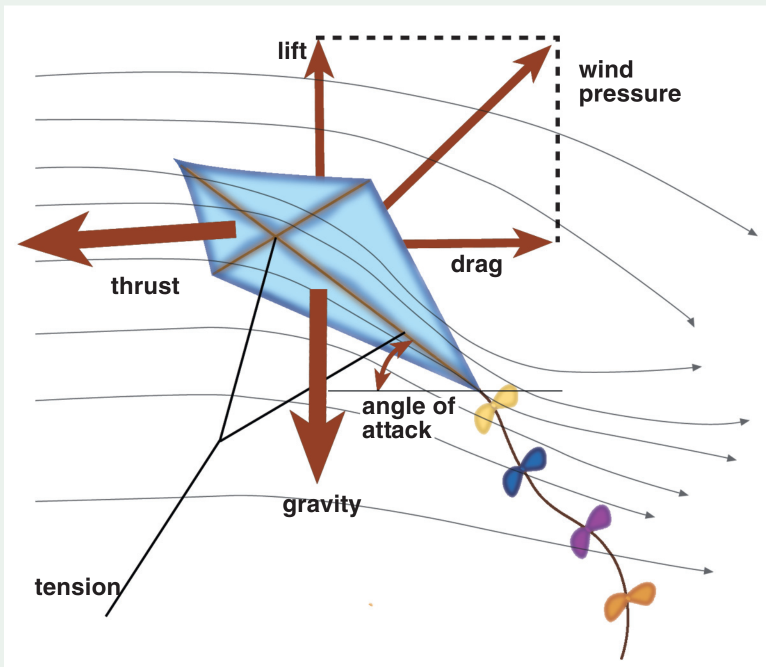
Put simply, a kite is an airfoil surface that flies when the forces of lift and thrust are greater than the forces of drag and gravity. In between flying and crashing to the ground are a variety of swoops, wiggles, pitches, yaws, and rolls that show the kite seeking a balance among the set of conflicting forces.

A kite creates an obstacle to the normal airflow (Peters 2001), which causes the air to change direction and speed. The air flows across one surface faster than it moves across the other side of that surface. The difference in speeds produces a pressure differential, resulting in lift in the direction of the surface with faster moving air. As air pressure can be altered by changing the kite's angle of attack, the changes in air speed result in changes in air pressure, which cause the kite to produce greater lift (see Figure 1).

Constructing a kite

The student activity in this article explains how to build a tetrahedron kite. The kites can then be used as the basis of a student-designed inquiry. Using tetrahedron cells to construct a kite offers numerous advantages. In principle, a kite constructed of tetrahedrons can be built to any size, simply by using combinations of tetrahedral cells. The cells are rigid, and do not require extra bracing to maintain their shape. This results in kites that become stronger and more stable as they increase in size without additional bracing or support.

FIGURE 1 **Forces acting on a kite**



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Flying tetrahedrons

Teacher notes for activities

- This lesson will take multiple days to complete—one or two days to demonstrate/model and construct a single cell; one day to construct multiple cells; and an additional day to attach tissue paper and construct tetrahedral kites.
- Arrange for permission (if needed) to conduct flying investigations during the days following the construction of kites. Based on characteristics of the class, additional adult (parent/guardian) assistance may be warranted.
- A large open field is most appropriate for kite-flying activities. Compile a set of kite-flying rules as a whole class, voting on the rules and consequences for violating safety considerations. See safety guidelines on page 27.
- Individual tetrahedrons stack easily and take up very little counter space.
- Student-constructed kites (made of 4 to 16 cells) are lightweight and can be hung from ceiling tile brackets, keeping the kites out of the way until needed. It may be advisable to consult with your custodial staff regarding any fire code concerns with hanging paper objects from the ceiling.
- Remind timekeepers to keep the group aware of the need to reel in kites well before the class has to return inside.
- Build some sample tetrahedrons at different stages of construction as visual aids for students.

Student questions to be answered before construction

- Which geometric solid has the smallest number of sides?
- How are triangles—single and multiple units—used in the construction of various structures such as bridges and towers?
- How does making an airplane larger allow it to carry larger and heavier objects?

Materials

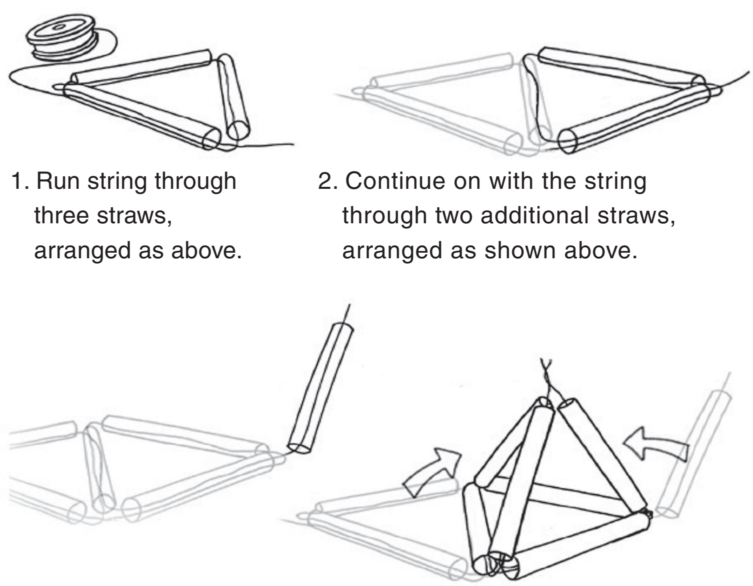
For each team of two students:

- 24 plastic drinking straws
- scissors
- glue
- 100 m of kite string
- 100 m of fishing line (approximately 30–60-pound test)
- two sheets of wrapping tissue, approximately 24" x 36" (standard size)
- darning needle (to assist in passing fishing line through straws)
- approximately 10 cm of masking tape (to hold straws in place while constructing tetrahedrons)
- astrolabe
- cardboard template for cutting tissue paper to proper size
- wind meter (optional)

Procedure

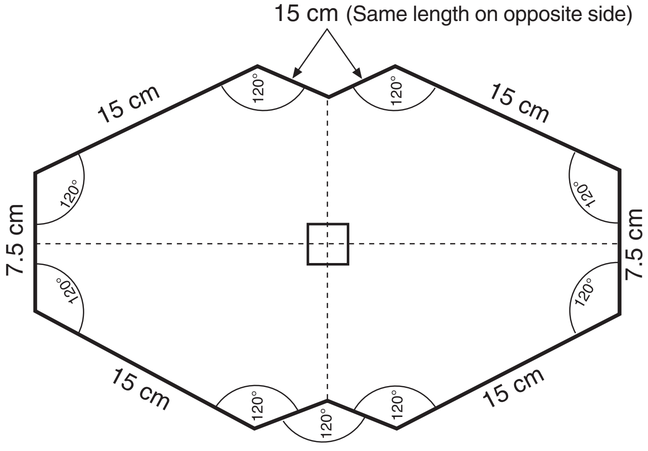
1. View the sample construction materials assembled by your teacher, including:
   - a tetrahedron constructed of straws
   - a tetrahedron with tissue paper covering two of the four sides
   - a tetrahedron kite, constructed with four tissue-covered tetrahedral cells organized into a single, larger tetrahedron
2. Work with your teammate to construct your own four-cell tetrahedron kite by following along as your teacher demonstrates the proper threading technique. Begin by taping three straws to the tabletop in an equilateral triangle. Thread fishing line onto the needle and string it through the straws as shown in Figure 2.
3. Use the template in Figure 3 to cut out a tissue-paper covering for two sides of the tetrahedron. Cover only two sides of the tetrahedron. Glue the covering over the frame, wrapping the excess materials around the straw framework.
4. Repeat steps 1 through 3 to create a total of four tetrahedrons (see Figure 4). Once you have the hang of it, continue to construct tetrahedrons in your spare time at home or at school until you have assembled 16.

FIGURE 2 Constructing kite cells



1. Run string through three straws, arranged as above.
2. Continue on with the string through two additional straws, arranged as shown above.
3. Take the string through one more straw.
4. Form a pyramid out of the straws and tie off the lead end of the strings.

FIGURE 3 **Tissue paper template**



5. Try to arrange your four tetrahedrons to create one larger tetrahedron. Once you have a successful arrangement, notify the teacher.
6. At the front of the room, observe how your teacher has arranged the four tetrahedrons so that the two covered faces of each are aligned the same way (see Figure 4). Arrange your tetrahedrons in this manner and bind them together at the corners with fishing line to hold them in place. Make sure all knots are pulled tight.
7. Create a bridle for your kite to which you will attach the kite string. First attach one end of a string to the apex of the pyramid and the other to one of the base corners. Attach one end of a second string to one corner of the base of the top tetrahedron and the other end across the front of the tetrahedron to the second corner (see Figure 5). Tie the two strings together where they cross. The kite string will be attached at this intersection. In general the strings should be taut and the bridle should be close to your kite.
8. Before going outside, review your kite-flying safety rules. Note that you should avoid running around with the kite, and instead allow the wind to lift the kite. If a wind meter is available, try to determine the minimum amount of wind needed to lift your kite.
9. As a class, carefully transport your kites to the area designated for flying. Attach 8 to 10 meters of string to the bridle. One person on your team should hold the string while the other should hold the kite off the ground. Once the kite is released, assuming there is enough wind, the kite will fly like an inverted pyramid with one point downward. It is the job of the student who released the kite to take an angle measurement with the astrolabe, which you will use later to determine the altitude reached by the kite.
10. Fly the kite for 10 to 12 minutes before returning to class. Take turns holding the string and taking astrolabe measurements.
11. Return to class and use your astrolabe reading to determine the height reached by the kite. Discuss with your teammate how the kite handled, any problems you had using the astrolabe, and any other observations you made during the flight.

Designing an experiment

Now that you have familiarized yourself with the characteristics of the tetrahedron kite, design an experiment to determine how changing one variable in the kite's design will affect its performance. For example, you could build a kite using:

- heavier tissue paper or a different kind of covering such as newspaper or cling wrap,
- 16 tetrahedron cells instead of four, or
- the same number of cells, but in a different arrangement.

Present your experimental design to the teacher for approval, including a sample of the data table you will use. Obtain any additional materials needed, such as a stopwatch, weights, and covering materials prior to next flight.

Safety

- Fly your kite where it will not cause a hazard to yourself or others. Kites should be flown in an open area, away from people, roads, and obstructions.
- Since kites and kite lines can be dangerous, safety should always be your primary concern. Be aware of your environment. If there is ever any question of safety, fly the kite in another location or on another day.
- Never fly your kite near power lines. If your kite becomes tangled in power lines, *leave it there* and notify your utility company of the situation.
- Never fly near cars.
- Never fly near an airport.
- Never fly in stormy weather or when a storm is approaching.
- Never fly over people.
- Avoid kite-eating trees.
- Always keep a safe distance from other fliers.

Tip: You can prevent problems by restricting the length of the line that you use. Make it shorter than the distance to the nearest obstacle!

Note: The most frequent injury during kite flying is sunburn. Be sure to protect yourself from the Sun with hats, sunglasses, and sunscreen.

Note: The second most frequent injury during kite flying is a cut or burn from the kite line. Do not allow the line to zip through your fingers. Do not use monofilament fishing line. For large kites, protect your hands by wearing leather gloves. These safety rules are found in Kites in the Classroom (*www.aka.kite.org/data/download/pdf/kitc.pdf*) and have been reprinted with permission from the American Kitefliers Association (*www.aka.kite.org*). AKA invites you to join them for National Kite Month (*www.nationalkitemonth.org*) in April. Register your kite-flying activity for a chance to win some kites and accessories.

FIGURE 4 Four-cell tetrahedron

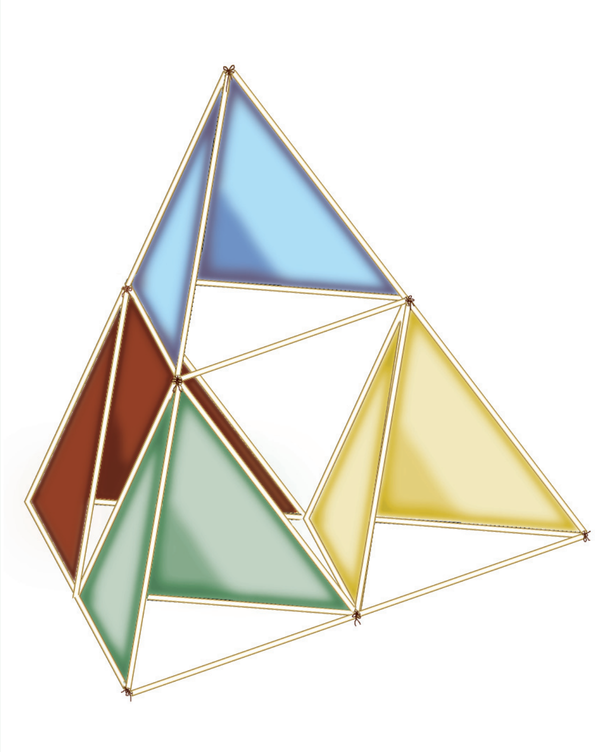
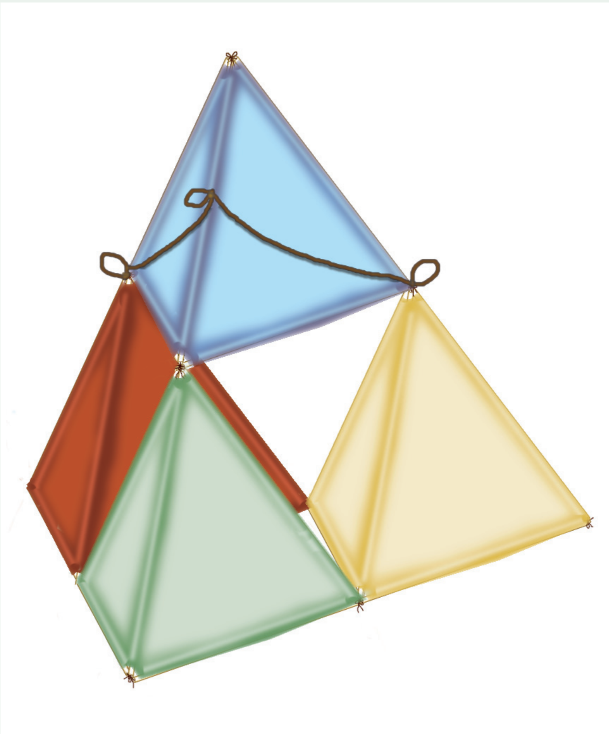


FIGURE 5 Bridle attachment



Constructing the kites requires plastic drinking straws, tissue paper, fishing line, glue, scissors, and a darning needle. An example of the basic tetrahedron cell is shown in Figure 2. Fishing line is threaded through the straws to maintain the tetrahedron's structure. The four surfaces are then covered in tissue paper (see Figure 3 for tissue paper template). Multiple tetrahedrons can be arranged to form even larger tetrahedrons. A set of four cells provides a good introduction to the operation of a tetrahedral kite (see Figure 4). More advanced or ambitious investigations would require a larger number of tetrahedral cells.

This is an inexpensive activity. For a class of 30 students, I spent $7 on straws, $6 on tissue paper, and a few more dollars on glue, fishing line, darning needles, and kite string. If your budget allows, you can experiment with graphite rods, ripstop nylon, and other high-tech materials. Visit the "Into the Wind" website at *www.intothewind.com* for instructions on making more permanent tetrahedral kites.

Testing kites

Testing the kites provides an opportunity to engage in hypothesis formulation and technological design studies. Students may be inspired by the work of Alexander Graham Bell, who investigated the structure, operation, and lifting capacity of tetrahedral kites at the end of the nineteenth, and beginning of the twentieth, century (Bell 1903).

One of the advantages of kite cells is that they can be quickly and easily modified so students can test many variables. For example, students can easily construct kites to compare the lifting power of a four-cell kite to that of a 16-cell kite, or they can alter the arrangement of the kite cells to see how designs affect stability.

Implementing the activities

The following activities are part of a broader, interdisciplinary unit that can be found at *www.cedu.niu.edu/scied/courses tlci525/unit_text.htm*. Before getting started, your students will need to know how to create and implement their own experiments and control variables. They should also be able to use an astrolabe to indirectly measure the height of the kites. (Instructions for building and using an astrolabe can be found on page 22 of the April 1997 issue of *Science Scope*. This article is also available free to members from our online archive at *www.nsta.org/middleschool*.) Two other useful resources for preparing your students for these activities are *Height-O-Meters* (Sneider, 1988) and *Experimenting with Model Rockets* (Sneider 1989), both from Lawrence Hall of Science.

Assessment

When assessing this activity, you should check to see if

- the kite construction demonstrates care and craftsmanship,
- the team consistently observed safety rules,
- a sound experimental design was created and followed, and
- an appropriate data table was created and meaningful data collected.

Conclusion

Interdisciplinary instruction works best when the experiences help students to learn content and processes in a broadly-based context. Whether arranged according to themes, skills, or concepts, interdisciplinary instruction offers the opportunity to engage a subject and many related experiences in greater depth and a more meaningful context. ■

Acknowledgment

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Additional resources

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Standards

Science

Understanding Concepts and Processes

- Evidence, models, and explanation

Science as Inquiry

- Abilities to do scientific inquiry
- Understandings about scientific inquiry

Physical Science

- Motion and forces

Science and Technology

- Abilities of technological design
- Understanding about science and technology

ADAPTED FROM *NSES*, TABLE 6.9, P. 110

Math

Important skills that relate to the geometry of kites were drawn from the National Council of Teachers of Mathematics standards. Specific standards that are supported by these activities include:

- Analyze characteristics and properties of two- and three-dimensional geometric shapes.
- Specify locations and describe spatial relationships using coordinate geometry and other representational systems.
- Apply transformations and use symmetry to analyze mathematical situations.
- Use visualization, spatial reasoning, and geometric modeling to solve problems.