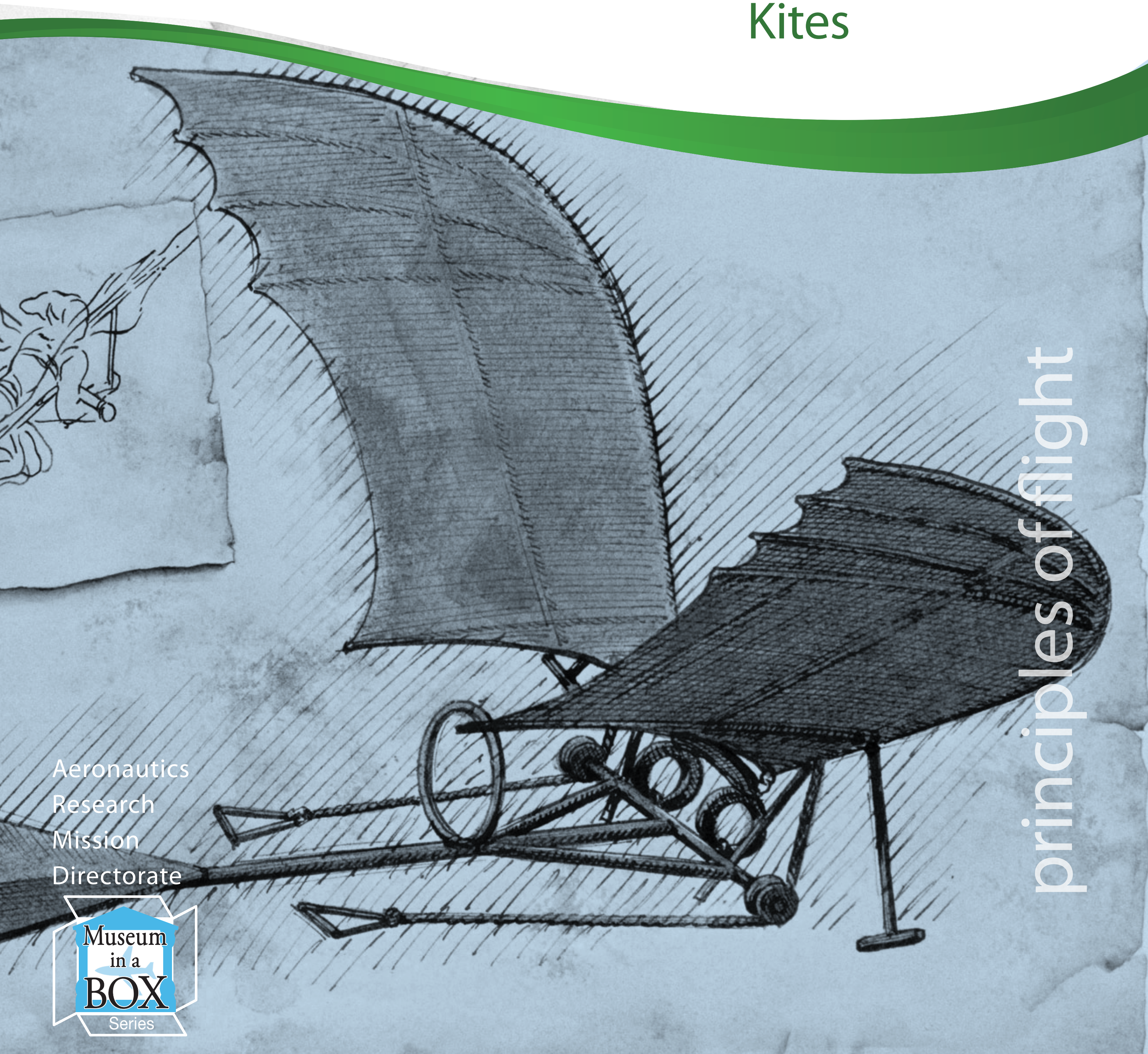
National Aeronautics and Space Administration

GRADES **5-12**

Kites



principles of flight

Aeronautics
Research
Mission
Directorate

Museum in a BOX Series

Kites

Lesson Overview

In this lesson, students will learn about the forces of nature such as wind and how they impact objects in the air. Students will discuss how wind acts on objects, how air moves, and how wind can be damaging (as in storms), but also helpful (wind power). They will make observations to identify the direction the wind is blowing and the approximate wind speed based on objects in nature and their movements.

Students will learn about motions and forces, transfer of energy, abilities of technological design, energy in the earth system, science as a human endeavor, and historical perspectives as they create their own kites and draw conclusions from their understanding of the power of wind as it applies to the activity of flying. By understanding that animals and humans can use nature's power of wind to accomplish different activities such as flying, students will learn how the forces of nature impact their daily lives.

Objectives

Students will:

1. Develop an understanding of certain geometric terms and use that understanding to build their kites.
2. Design and build a tetrahedron.
3. Visualize tetrahedrons in three dimensions.
4. Calculate how many tetrahedrons will be necessary to assemble a large kite.
5. Find number patterns from sequences.
6. Understand the four forces of flight and basic wind flow.
7. Be able to identify the direction wind is blowing.
8. Be able to approximate the speed of the wind using the Beaufort scale .

Materials:

In the Box

Sets of six (6) eight-inch straws for every team of 3-4 students

Sets of four (4) 3 x 5 cards for every team of 3-4 students

Sets of six (6) straws (no longer than 8 inches) for every team of 3-4 students. (*NOTE: The straws need to be straight and of uniform length. If only flexible straws are available, then they need to be cut to remove the flexible portion. Each tetrahedral cell needs 6 straws.*)

2-3 large spools of cotton string. (*NOTE: Consider cutting the string ahead of time. Each piece = 4 feet long*)

Scissors

Hot Glue Gun (recommended for instructors use only)

Hot Glue Gun Sticks (recommended for instructors use only)

Colored tissue paper

Ruler

Glue sticks

Store bought kites

Meter stick

Digital anemometer

Provided by User

Unsharpened pencils
(1 per team of students)

GRADES 5-12

Time Requirements: 5 - 5½ hours

Background

Kites have dazzled our skies for over 2,000 years. Using silk and bamboo, the Chinese were the first to fly kites. The Japanese flew kites mostly for religious reasons. Oftentimes kites were fitted with whistles or strings in order to make musical sounds while in flight. Kites were decorated with mythological themes or legendary figures to show respect as well. It was not until the 18th century that kites were used and taken seriously in Europe. Kites became more than just important religious symbols; they had become instruments of scientific research. The "Golden Age of Kiting," is said to have occurred from 1860 to 1910. Kites were used for meteorology, aeronautics, wireless communication and photography. After the Wright Brothers flew their "Wright Flyer," in 1903, interest in kites diminished and by WWII, kites had become a toy used primarily for recreation.

(Public Domain)

Img. 1 Children flying kites

(Public Domain)

Img. 2 Cody manlifter

While we are not exactly sure when the first kite was flown, it has been documented that Chinese General Han Hsin flew a kite over the wall of a city he was attacking around the year 200 B.C. He wanted to measure how far his army would have to tunnel underneath the city in order to reach past its defenses. Another story recounts that nearly 300 years ago a thief used a large kite to carry himself to the top of a castle so he could steal a golden statue from the roof.

Kites also were used to carry cameras and meteorological instruments. The British, French, Italian, and Russian armies utilized kites during World War I for immediate observations and signaling. During World War II however, the United States Navy found other uses for kites. For example, kites were flown to prevent airplanes from flying too low over targets, used for target practice, and if pilots were lost at sea they would raise a kite so they could be found.

Samuel Cody came to the attention of the English War Office after he crossed the English Channel in a boat drawn by a kite. He continued his experiments with passenger kites and lifted a person to a new record high of 1600 feet. Cody's design was adopted in 1906, and his war kites were used for observation until they were later replaced by aircraft.

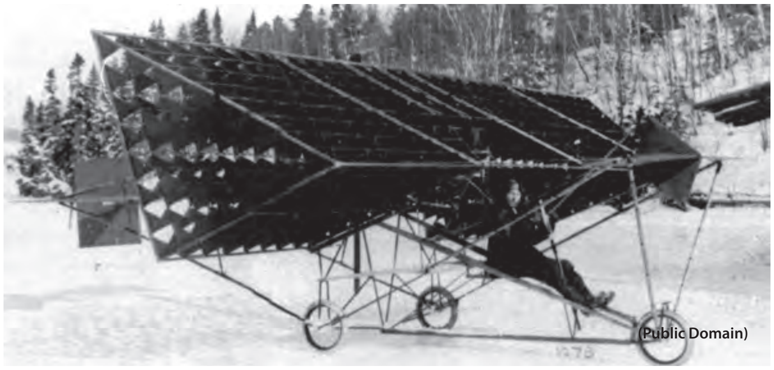
Eventually Cody's interest turned to gliders, which was based largely on his kite designs. Cody and his kite had a profound impact on the British Army. He became the chief instructor in kiting at the balloon school in Aldershot, England. It was also during this period of time that Cody built a motorized kite. He wanted to develop one of his motorized kites into a man-carrying airplane. However, the British Army was more interested in airships during 1907 than they were in airplanes.

Img. 3 Samuel Cody

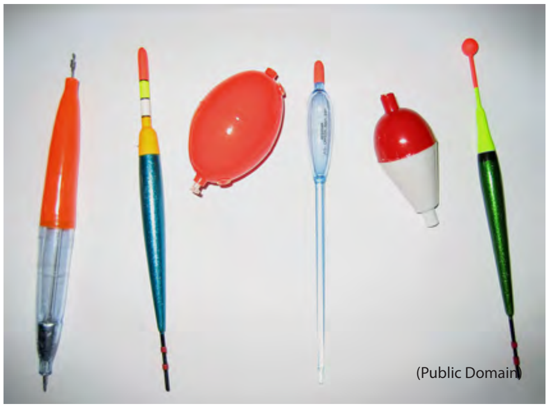
Perhaps one of the most interesting kites in history was one constructed by Alexander Graham Bell. His kite was specifically designed to carry people. Bell believed that the best type of kite to do this was a tetrahedron kite. A tetrahedron is essentially a triangular pyramid: a three-dimensional figure with four equilateral triangles.

His first kite, called the Frost King, was comprised of 256 cells or tetrahedrons. Bell was determined to build a kite that could carry a man, and therefore, increased his tetrahedron kite structure from 256 cells to 1300. In 1907, Bell built another kite which he called the Cygnet. It was the first kite he had ever designed, manned with a person and then flew. The kite contained 3,393 cells and had floats attached to the bottom so it could land on water. Just imagine how it must have felt to fly that kite! Graham's kite flew for 7 minutes and went as high as 168 feet.

When we think of kites today, we usually think of them as recreational. For example, something a family would do at a park on a windy day. Interestingly, kites have had many useful purposes in the past and continue to, even to this day. Fisherman today use something called a "bobber," to help them determine when a fish bites their line.



Img. 4 Bell's tetrahedron kite



Img. 5 Fishing bobbers

Imagine fishing from the beach. What can a kite do that a regular fishing pole could not? The kite can take a fishing line far offshore where larger fish are located. The normal distance a fisherman can cast his pole cannot reach the same distance that a kite could be flown. Long-ago Chinese fishermen actually used kites in the same manner. They would tie fishing line to the end of their kite, and when the fish took the bait, the kite would move.

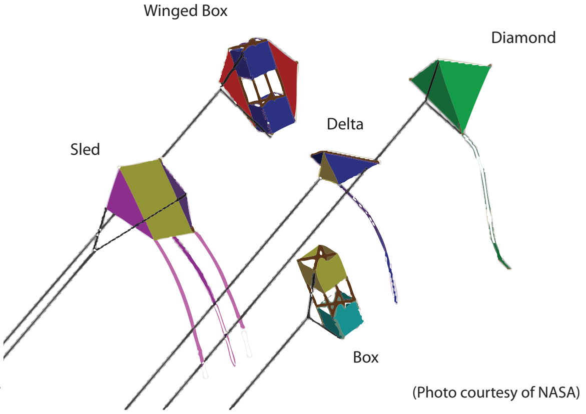
Today, farmers use scarecrows to keep birds away that would eat their crops. Chinese farmers would use kites in their fields in much the same manner. Kites were also used for testing the wind, measuring distances, and signaling. During WWII, kites were used by Navy anti-aircraft gunners for target practice. The military used kites because they maneuver in the air in a similar fashion to the fighter aircraft that the gunners were responsible for defending their battleships against. Kites are still used today by the military for target practice. Scientists use kites as well to conduct experiments and to gather meteorological readings. Competitions are held for stunt kites and for recreational use. Their design has expanded beyond the known diamond and box kites.

Img. 6 Kite fishing

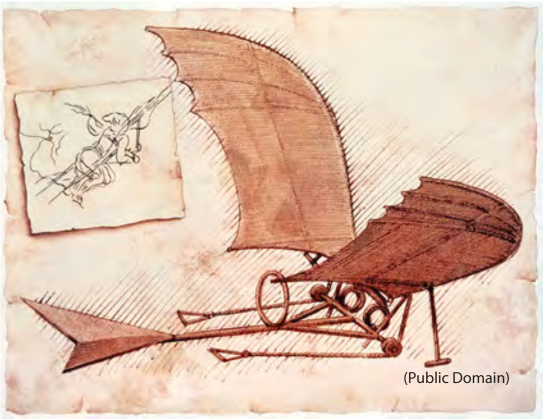
Img. 7 Scarecrow

There are many types of kites, and over the years the materials used to build kites has changed. Materials have included silk, bamboo, string, plastic, nylon, wood and more. NASA has classified five different types of kites. Reviewing the different kites will help you as the teacher, and will help prepare your students for this lesson. The five types of kites discussed in this lesson are the Winged Box, the Sled, the Delta, the Box Kite, and finally the Diamond. All kites must be lightweight and strong to endure powerful winds. A solid frame made usually of wood or plastic serves as the base of the kite, while paper, plastic, or cloth serve as the kite's skin. Kites will range in abilities based on their construction. Some kites are very stable while others are extremely maneuverable. Kites also can soar to high altitudes and others can perform magnificent stunts.

Img. 8 A modern kite



Img. 9 Types of kites

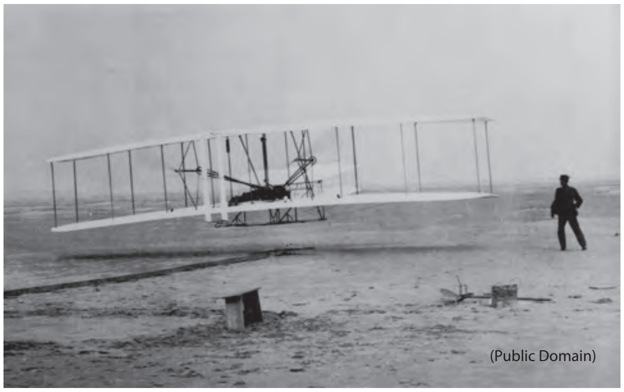


Img. 10 Leonardo da Vinci's Ornithopter

Many of us have seen the famous picture of Benjamin Franklin and his kite (Img. 5). However, Franklin was not the first one to use kites in a scientific fashion. During the late 1400s, Leonardo da Vinci began to study flight by observing birds. Later he flew kites which inspired him to design flying machines.

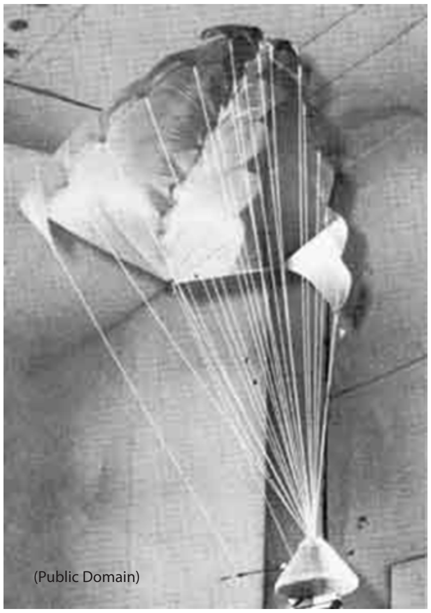
Img. 11 Benjamin Franklin flying his kite

In 1899, the Wright Brothers built a bi-plane kite, which was the kite that was used to invent wing warping, a significant discovery. The Wright Brothers gained further insight about how to create the world's first working flying machine by learning that the wings of a kite could be twisted or warped. By finding a way to twist the wings, it gave them greater control of their kite. This led to their creation of gliders, which then led to their invention of the Wright Flyer.

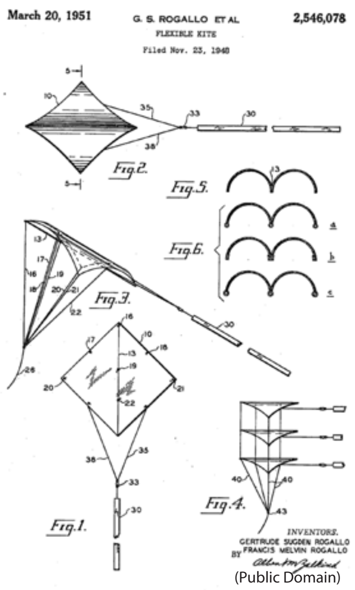


Img. 12 Wright flyer

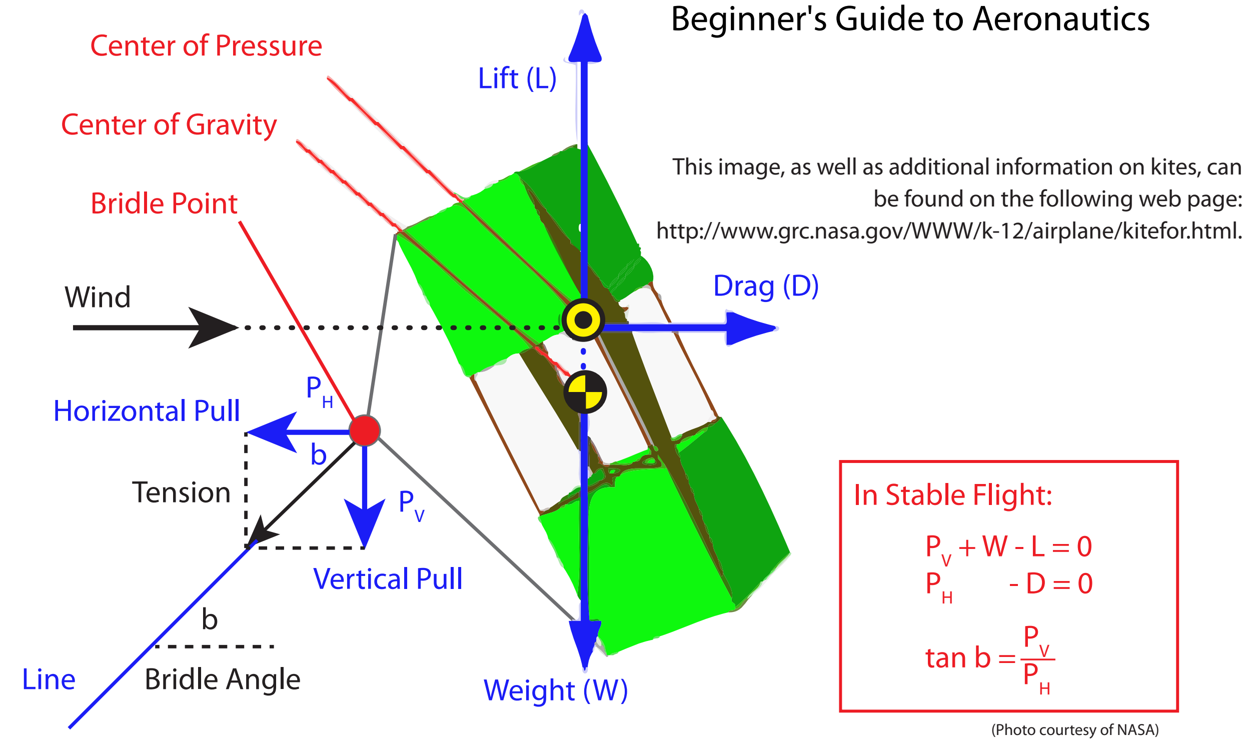
Created by Gertrude and Francis Rogallo in 1948, the Rogallo wing or parawing is a flexible type of airfoil. This flexible wing was considered by NASA to be an alternate recovery system for the Gemini space capsule. Composed of two partial conic surfaces, both cones point forward and is considered to be a simple and inexpensive flying wing that has many remarkable properties. The Rogallo wing itself cannot be classified as a powered aircraft glider or kite. The way in which the wing is attached and manipulated does not allow it to be classified as a kite or glider. It has been used in toy kites, spacecraft parachutes, ultralight powered air craft, gliders, and in sport parachutes. What makes the wings so special is that it is designed to bend and flex in the wind. This provides favorable dynamics which can be compared to a spring suspension in an automobile.



Img. 13 Rogallo's wing



Img. 14 Rogallo patent



Img. 15 Forces on a kite

Similar to airplanes, kites are affected by wind and the four forces of flight; weight or gravity, lift, drag, and thrust. When a kite flies, it overcomes the force of gravity because the force of the wing and its pressure on the kite's surfaces helps to push it upward. Since kites are heavier than air, they weigh more than the volume of the air they displace. The air pressure increases as the wind hits the face or front surface of the kite.

The air blowing onto the face of the kite, traveling around its sides and down the kite's backside creates a low pressure area above the kite. When the wind hits the front of the kite, the wind is deflected downward, and there is a force in the opposite direction, which pushes the kite upward. This action depicts Newton's Third Law of Motion, which states that for every action there is an equal and opposite reaction. The shape of the kite affects the distribution of the aerodynamic forces. All of these things come into play when flying a kite, whether for fun or for scientific experimentation.

When we describe the four forces interacting with an airplane, we think of the airplane surrounded by a bubble of those four forces. You also can think of the four forces acting on a kite in the same manner, especially when imagining aircraft gliders. The Wright Brothers were well aware of these evident similarities and therefore, engaged in a series of kite experiments to investigate the aerodynamics of unpowered or glider aircraft in the early 1900s. Kites also taught them about the basics of flight control.

As previously mentioned, the four forces of flight are weight or gravity, lift, drag and thrust. On an airplane, thrust works against drag to keep the airplane moving forward. However, the tension in a kite's string works against the drag. This will be explained in greater detail later in the lesson. Weight (caused by gravity) is a force that is always directed toward the center of the earth. Gravity is what keeps us grounded, literally, on the planet. Gravity gives us the perfect balance necessary to perform our daily tasks, whether it is walking, driving, working, or playing.

An airplane rotates around the center of gravity, which is the average location of the weight of the airplane. However, a kite rotates around the connection point of its control wires or kite strings. The weight of the kite is always directed toward the center of the earth.

In order to make anything fly, a force must be generated to overcome its weight. The same idea applies to a kite. This force is called lift. For the kite, lift is generated by the motion of air around the kite. When air moves past a kite, there is some resistance, which causes a force on the kite known as drag. While lift is an upward force (perpendicular to the wind), drag is a force that acts in the same direction as the wind.

Tension on a kite is used to overcome drag, and is created through the string attached to the kite which keeps it in a fixed location. Without the string to anchor it, the kite would drift in the direction of the wind. For a kite to generate lift, the wind must be moving past it. If the kite is drifting with the wind, the wind is not blowing past it, so the kite will eventually fall to the ground because of gravity.

It is important to note that tension can be broken down into two different components: vertical and horizontal. Once the kite is stable in flight, the lift of the kite is equal to the weight plus the vertical component of the tension. The drag is equal to the horizontal tension. If we want to compare an airplane and a kite, the horizontal pull of the string tension on a kite is similar to the role of the thrust on an airplane.

Without wind, it is very hard to fly a kite. Some days the wind is too calm for a kite to take flight or to conduct kite experiments. Other times flying a kite would not be optimal, for example, during a thunderstorm. Today, we have a variety of meteorological instruments that can measure the wind, weather, and temperature. However, prior to the 1800s, we had to guess the wind speed. That changed when Sir Francis Beaufort, who was serving on the HMS Woolwich in 1805, devised a scale to measure wind speed based on his observations of nature and man-made objects. His sea-based wind observation system, now referred to as the Beaufort Scale (Fig. 1), standardized the measurement of wind using a 0-12 rating scale. The ratings were based on the estimated wind knots through observation of what could be seen from the ocean to trees on land. Eventually, the scale was adapted from sea to land which is what we will learn about in this lesson.

Using the Beaufort scale while at sea is a tool that most boat captains still use today. In addition, the BBC radio in the United Kingdom uses it for shipping forecasts, as does the Irish Meteorological Service. China, Greece, Hong Kong and Taiwan also use this scale.

Humans have always been fascinated with flying. Before we could wrap our heads around something like Leonardo da Vinci's Orinthopter, we managed to fly high in the sky aboard man-carrying kites. Kites have dazzled our skies and our imagination for over 2,000 years. We have learned that kites were made of different materials and that over the years these materials have become more advanced as technology in construction has improved. The creativity of those who have been involved in designing kites is remarkable. Their purposes range from fishing, to farming, to military intelligence and scientific experiments which show how diverse kites have been and continue to be to this day.

Fig. 1 The Beaufort scale

Beaufort number	Description	Wind speed	Wave height	Sea conditions	Land conditions
0	Calm	< 1 km/h (< 0.3 m/s) < 1 mph < 1 kn < 0.3 m/s	0 m 0 ft	Flat.	Calm. Smoke rises vertically.
1	Light air	1.1–5.5 km/h (0.3-2 m/s) 1–3 mph 1–2 kn 0.3–1.5 m/s	0–0.2 m 0–1 ft	Ripples without crests.	Smoke drift indicates wind direction and wind vanes cease moving.
2	Light breeze	5.6–11 km/h (2-3 m/s) 4–7 mph 3–6 kn 1.6–3.4 m/s	0.2–0.5 m 1–2 ft	Small wavelets. Crests of glassy appearance, not breaking.	Wind felt on exposed skin. Leaves rustle and wind vanes begin to move.
3	Gentle breeze	12–19 km/h (3-5 m/s) 8–12 mph 7–10 kn 3.4–5.4 m/s	0.5–1 m 2–3.5 ft	Large wavelets. Crests begin to break; scattered whitecaps.	Leaves and small twigs constantly moving, light flags extended.
4	Moderate breeze	20–28 km/h (6-8 m/s) 13–17 mph 11–15 kn 5.5–7.9 m/s	1–2 m 3.5–6 ft	Small waves with breaking crests. Fairly frequent whitecaps.	Dust and loose paper raised. Small branches begin to move.
5	Fresh breeze	29–38 km/h (8.1-10.6 m/s) 18–24 mph 16–20 kn 6 8.0–10.7 m/s	2–3 m 6–9 ft	Moderate waves of some length. Many whitecaps. Small amounts of spray.	Branches of a moderate size move. Small trees with leaves begin to sway.
6	Strong breeze	39–49 km/h (10.8-13.6 m/s) 25–30 mph 21–26 kn 10.8–13.8 m/s	3–4 m 9–13 ft	Long waves begin to form. White foam crests are very frequent. Some airborne spray is present.	Large branches in motion. Whistling heard in overhead wires. Umbrella use becomes difficult. Empty plastic garbage cans tip over.

Fig. 1 The Beaufort scale (cont.)

Beaufort number	Description	Wind speed	Wave height	Sea conditions	Land conditions
7	High wind, Moderate gale, Near gale	50–61 km/h (13.9-16.9 m/s) 31–38 mph 27–33 kn 13.9–17.1 m/s	4–5.5 m 13–19 ft	Sea heaps up. Some foam from breaking waves is blown into streaks along wind direction. Moderate amounts of airborne spray.	Whole trees in motion. Effort needed to walk against the wind.
8	Gale, Fresh gale	62–74 km/h (17.2-20.6 m/s) 39–46 mph 34–40 kn 17.2–20.7 m/s	5.5–7.5 m 18–25 ft	Moderately high waves with breaking crests forming spindrift. Well-marked streaks of foam are blown along wind direction. Considerable airborne spray.	Some twigs broken from trees. Cars veer on road. Progress on foot is seriously impeded.
9	Strong gale	75–88 km/h (20.8-24.4 m/s) 47–54 mph 41–47 kn 20.8–24.4 m/s	7–10 m 23–32 ft	High waves whose crests sometimes roll over. Dense foam is blown along wind direction. Large amounts of airborne spray may begin to reduce visibility.	Some branches break off trees, and some small trees blow over. Construction/temporary signs and barricades blow over.
10	Storm Whole gale	89–102 km/h (24.7-28.3 m/s) 55–63 mph 48–55 kn 24.5–28.4 m/s	9–12.5 m 29–41 ft	Very high waves with overhanging crests. Large patches of foam from wave crests give the sea a white appearance. Considerable tumbling of waves with heavy impact. Large amounts of airborne spray reduce visibility.	Trees are broken off or uprooted, saplings bent and deformed. Poorly attached asphalt shingles and shingles in poor condition peel off roofs.
11	Violent storm	103–117 km/h (28.6-32.5 m/s) 64–72 mph 56–63 kn 28.5–32.6 m/s	11.5–16 m 37–52 ft	Exceptionally high waves. Very large patches of foam, driven before the wind, cover much of the sea surface. Very large amounts of airborne spray severely reduce visibility.	Widespread damage to vegetation. Many roofing surfaces are damaged; asphalt tiles that have curled up and/ or fractured due to age may break away completely.
12	Hurricane force	≥ 118 km/h (≥ 32.8 m/s) ≥ 73 mph ≥ 64 kn ≥ 32.7 m/s	≥ 14 m ≥ 46 ft	Huge waves. Sea is completely white with foam and spray. Air is filled with driving spray, greatly reducing visibility.	Very widespread damage to vegetation. Some windows may break; mobile homes and poorly constructed sheds and barns are damaged. Debris may be hurled about.

Activity 1 As the Wind Blows

GRADES 5-12

Time Requirements: 30 minutes

Materials:

In the Box

Digital anemometer

Provided by User

None

Worksheets

Beaufort Wind Scale (Worksheet 2)

Reference Materials

Beaufort Wind Scale (Figure 1)

Key Terms:

Beaufort Wind Scale

Objective:

Through experimentation, students will:

1. Understand the Beaufort Wind Scale.
2. Estimate and measure the wind outside

Activity Overview:

Students will work together to fill out instructional worksheets to measure the wind speed outside.

Activity:

1. **Discuss with the students that before there were instruments to measure the wind, people estimated the wind speed based on observations of nature and the environment outside.** This is called the Beaufort Wind Scale. Pass out the Beaufort Wind Scale Student Worksheet.

2. **Invite students to use their powers of deduction to fill out the blank Beaufort Wind Scale Student worksheet based on discussions and critical thinking within their group.**

3. **When the students are finished filling out their Beaufort Wind Scale student worksheet take the class outside and used to digital anemometer to take wind readings and discuss the class.**

4. **Once the students are finished, distribute copies of a complete Beaufort Wind Scale. Give students an opportunity to make any changes necessary to align their chart with the original Beaufort Scale.**

NATIONAL SCIENCE STANDARDS 5-8

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

NATIONAL SCIENCE STANDARDS 9-12

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

EARTH AND SPACE

- Energy in the earth system

SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

Activity 2

The Great Straw Pyramid

GRADES 5-12

Time Requirements: 45 minutes

Materials:

In the Box

None

Provided by User

Sets of six (6) straws (no longer than 8 inches) for every team of 3-4 students

Sets of four (4) 3 x 5 cards for every team of 3-4 students

Worksheets

Shape Define and Design (Worksheet 1)

Clue Cards (if needed)

Reference Materials

None

Key Terms:

Apex
Equilateral
Equilateral Triangle
Pyramid
Tetrahedron
Triangle
Vertices

Objective:

Through experimentation, students will:

1. Be able to explain the various shapes learned in this activity, including equilateral triangle, pyramid, tetrahedron, and triangle.
2. Build a tetrahedral pyramid using 6 straws.
3. Work in teams to develop designs, test theories, and construct a final build.

Activity Overview:

Students will be given definitions of the shapes that they will be working with, including equilateral triangle, pyramid, tetrahedron, and triangle. They will be asked to rewrite the definition in their own words and to draw a picture of the shape based on their definition. Once students grasp the shapes and their concepts, 6 straws will be passed out to each team and the students will be asked to create four equilateral triangles with the 6 straws. Students may not cut nor bend the straws to complete this task. They may not use glue or tape of any kind. The only items allowed will be the straws. The Shape, Design, and Define Worksheet will be provided for students to work in a two-dimensional environment (if they feel drawing will help them complete the task) before attempting to build the three-dimensional version.

Activity:

1. **Divide the students into groups of 3-4 students per team**.
2. **Pass out one set of six straws to each team.**
3. **Pass out the Shape, Define, and Design Worksheets.**
4. **Explain to the students that they will need to complete the worksheets together as a team first.** Once that step is completed, they will then need to assemble four equilateral triangles with the straws. Remind them that they may not cut or bend the straws or use any type of adhesive.
5. **Give the students approximately 20 minutes to complete the worksheets, and an additional 10-15 minutes to arrange the straws once the worksheet is finished.** The goal is to see if the students can devise a solution that will create four equilateral triangles with as little help from the teacher as possible.

6. **After about 10-15 minutes, if the teams have not been able to assemble the four equilateral triangles, tell them they can approach you and ask for a clue.**

7. **Give the students Clue #1 to take back to their team.** Based on the information given in the clue, they should be able to try and assemble the four equilateral triangles. If they are not able to do so, after a few minutes they can come up and get the next clue. Students may repeat these steps and acquire up to four clues in order to solve their puzzle.

8. **Write the following four clues each on 3 x 5 cards (One set of 4 clues per team)**.

   Clue #1 – *Another word for a triangular pyramid is a tetrahedron. Tetra means four and hedron means face.*

   Clue #2 – *To build a tetrahedron, you need four equilateral triangles and four vertices. A vertex is a common point between two line segments. So in a regular triangle there would be three vertices. It may help to sketch your design.*

   Clue #3 – *If sketching your design is two dimensional, then, when you build your tetrahedron it would be in terms of ______ dimensions. (The students should figure out the answer is 3.)*

   Clue #4 – *Draw a picture of a tetrahedron or find a picture of one, and attach it to the clue card.*

NATIONAL SCIENCE STANDARDS 5-8

SCIENCE AS INQUIRY

• Abilities necessary to do scientific inquiry

• Understandings about scientific inquiry

SCIENCE AND TECHNOLOGY

• Abilities of technological design

• Understanding about science and technology

NATIONAL SCIENCE STANDARDS 9-12

SCIENCE AS INQUIRY

• Abilities necessary to do scientific inquiry

• Understandings about scientific inquiry

SCIENCE AND TECHNOLOGY

• Abilities of technological design

• Understanding about science and technology

NATIONAL MATH STANDARDS 5-12

NUMBER AND OPERATIONS

• Understand numbers, ways of representing numbers, relationships among numbers, and number systems

• Understand meanings of operations and how they relate to one another

• Compute fluently and make reasonable estimates

GEOMETRY

• Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships

• Use visualization, spatial reasoning, and geometric modeling to solve problems

MEASUREMENT

• Understand measurable attributes of objects and the units, systems, and processes of measurement

• Apply appropriate techniques, tools, and formulas to determine measurements.

DATA ANALYSIS AND PROBABILITY

• Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them

PROCESS

• Problem Solving

• Communication

• Connections

• Representation

Activity 3 Triangular Numbers

GRADES 5-12

Time Requirements: 45 minutes

Materials:

In the Box

None

Provided by User

None

Worksheets

Triangles in Numbers (Worksheet 3)

Reference Materials

None

Key Terms:

Triangular Numbers

Objective:

Through experimentation, students will:

1. Understand triangular numbers in order to build a tetrahedral kite.

Activity Overview:

Students will work together to complete instructional worksheets to better help them understand how a tetrahedral kite is constructed.

Activity:

1. **Pass out the Triangles in Numbers Worksheet.** Explain that a tetrahedron is represented mathematically on this sheet.
2. **Ask the students to fill out the mathematical representations through 10 levels.** The first five levels are done for them on the worksheet.
3. **When the students are done go over the answers with them.**

NATIONAL MATH STANDARDS 5-12

NUMBER AND OPERATIONS

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems
- Understand meanings of operations and how they relate to one another
- Compute fluently and make reasonable estimates

GEOMETRY

- Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships
- Use visualization, spatial reasoning, and geometric modeling to solve problems

MEASUREMENT

- Understand measurable attributes of objects and the units, systems, and processes of measurement
- Apply appropriate techniques, tools, and formulas to determine measurements.

DATA ANALYSIS AND PROBABILITY

- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them

PROCESS

- Problem Solving
- Communication
- Connections
- Representation

Activity 4 Tetrahedral Kite Engineering

GRADES 5-12

Time Requirements: 90-120 minutes

Materials:

In the Box

4 sets of 6 straws (8 inches or less) for every team of 3-4 students. (*NOTE: The straws need to be straight and of uniform length. If only flexible straws are available, then cut them to remove the flexible portion OR tape the flexible portion. Each tetrahedral cell needs 6 straws.*)

2-3 large spools of cotton string. (*NOTE: Consider cutting the string ahead of time. Each piece = 4 feet long*)

Scissors

Hot Glue Gun (recommended for instructors use only)

Hot Glue Gun Sticks (recommended for instructors use only)

Colored tissue paper

Ruler

Glue sticks

Store-bought kites

Meter stick

Provided by User

Unsharpened Pencils (1 per team)

Worksheets

Tetrahedral Kite Engineering (Worksheet 4)

Objective:

Through experimentation, students will:

1. Develop an understanding of numerous geometric terms including: base, edge, face, parallelogram, platonic solid, pyramid, quadrilateral, rhombus, tetrahedron, and vertex.
2. Create a tetrahedron kite.
3. Visualize a series of tetrahedrons in three dimensions to better understand how to construct it.

Activity Overview:

Working in teams, students will create and build a tetrahedral kite. Once students have completed their kite, they will have a chance to fly their kites outside.

Activity:

Caution: This is a highly engaging and hands-on activity. Extra assistance that day is advised.

Give each student the Tetrahedral Kite Engineering Student Worksheet. Prior to each step, read the directions aloud to the class and then allow them to proceed with the assembly. Also, circulate among the teams, so if students have questions, you are available.

Step One - Create a Tetrahedron Cell - Read these steps aloud to the class.

1. **You will need the following supplies for this step: string, 6 straws (no longer than 8 inches long), scissors, and a flat surface.**
2. **First, cut a length of yarn/string four (4) feet long. (If the cut string has not already been provided.)**
3. **Second, take 6 straws and place them flat on the surface.**
4. **Use your piece of string to join 3 straws together. One end of the "joined" 3 straws should have two strings extended, 1) approximately 20 inches long, and 2) approx. 4 inches long.**
5. **Tie these two ends of the string tightly together to make sure that there is no room for the triangle to "wiggle."**

Reference Materials

Figures 2 - 17

Key Terms:

Base

Edge

Face

Parallelogram

Pyramid

Rhombus

Tetrahedron

Vertex

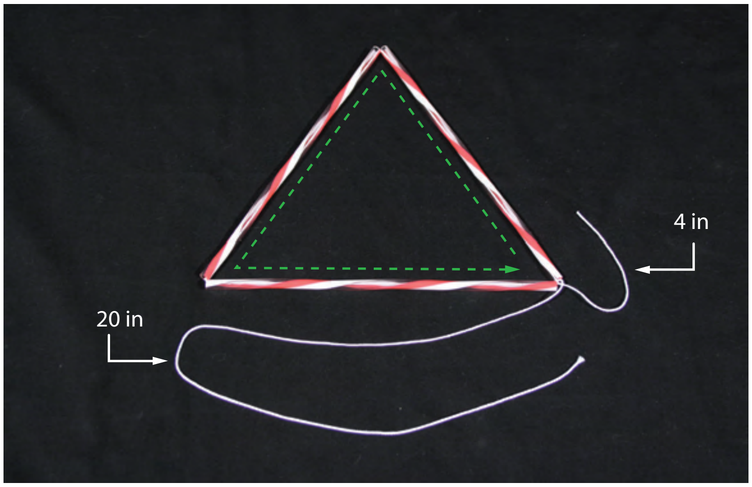


Fig. 2 Triangle

Step Two - Create a Rhombus - Read these steps aloud to the class.

1. **The three "joined" straws should form a tight triangle.**
2. **Cut another 4-inch piece of string.**
3. **Take one end of the 4-inch string, and tie that end to any empty corner of the triangle.**
4. **Now, add 2 more straws onto the longest piece of string.**

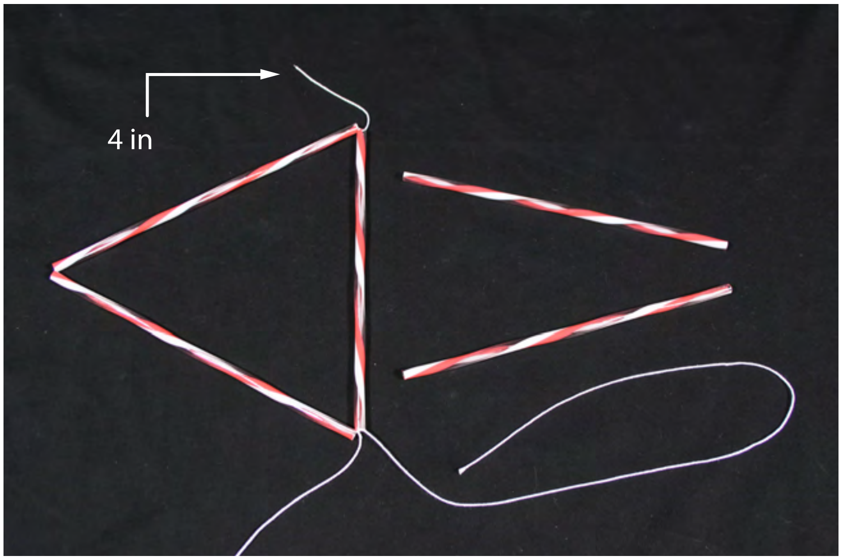


Fig. 3 Rhombus construction

5. **Next, take the string that holds the two additional straws and tie it to the end of the 4-inch string closest to the straw to make another tight triangle. See picture below:**

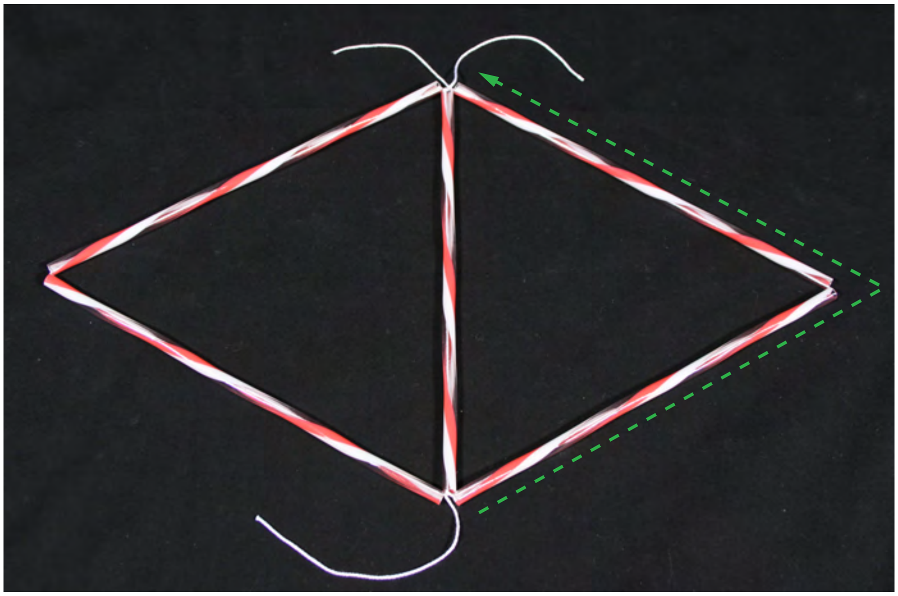


Fig. 4 Completed rhombus

Step Three - Create a Three Dimentional Thetrahedron - Read these steps aloud to the class.

1. **Cut another 4-inch piece of string.**
2. **Take that 4-inch piece of string and tie one of its ends to one of the empty corners.**
3. **Next, cut a piece of string that is double the length of one straw (or side of a tetrahedron).**

4. **Tie one end of that double-length string to the remaining empty corner. See picture below:**

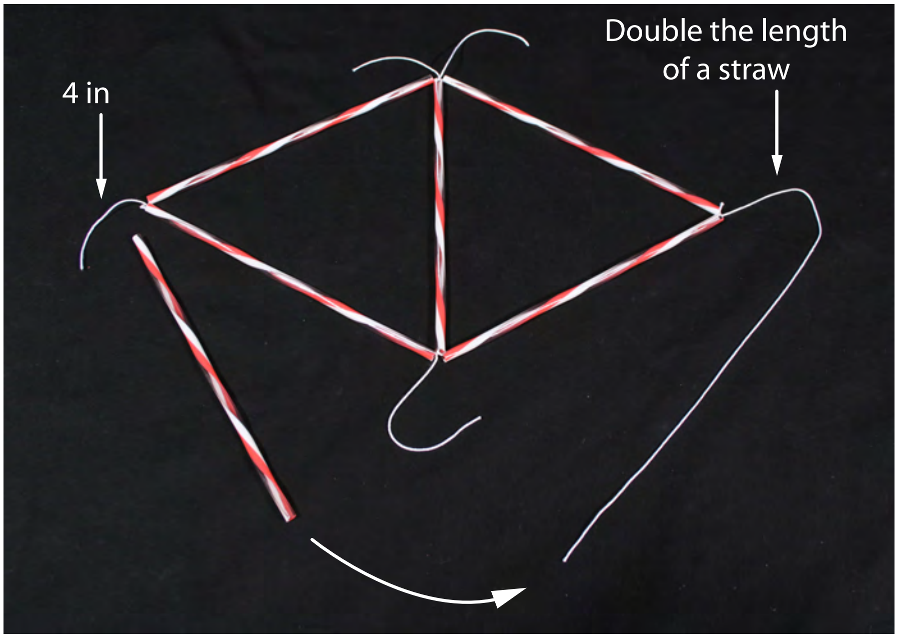


Fig. 5 Three dimensional tetrahedron construction

5. **Now, add the last straw onto the double-length string.**
6. **Tie together the two opposite ends (the end of the 4-inch string and the end of the double-length string closest to the straws) to form a tight 3-dimensional tetrahedron (fig. 6).**
7. **Follow all numbered instructions in Steps 1, 2 and 3 to create a second tetrahedron. You will need two tetrahedrons to execute the Steps Four and Five.**

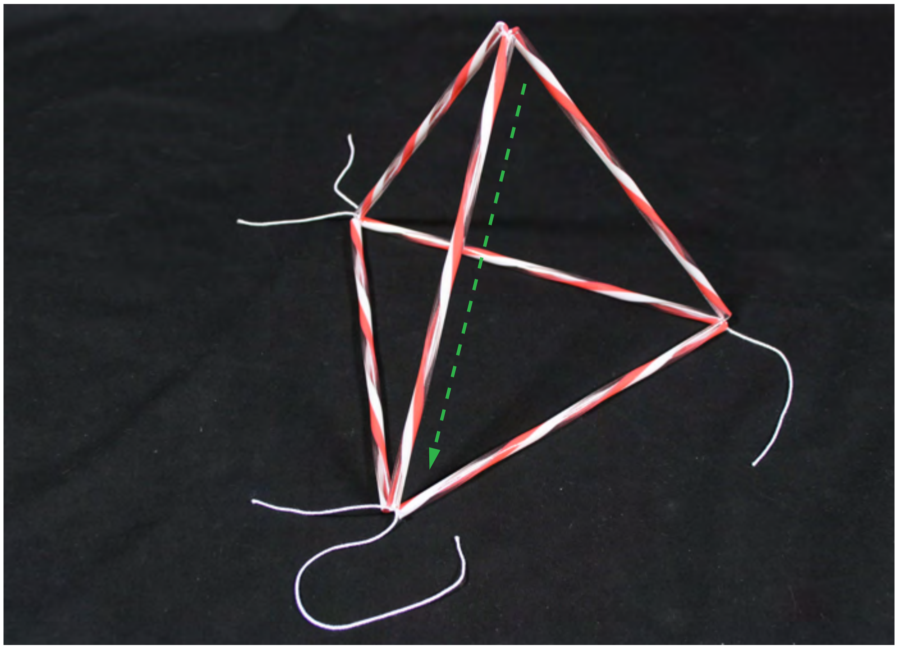


Fig. 6 Completed three dimensional tetrahedron

Step Four - Create a Thetrahedron Tissue Paper Cover - Read these steps aloud to the class.

1. **Choose a piece of colored tissue approximately 24 inches x 18 inches.**

2. **Place two tetrahedrons side-by-side in the middle of the 24" x 18" tissue. (It might help to lightly place a piece of tape in the middle of the tetrahedrons to hold them in place for marking purposes.)**

3. **At each corner of the two "joined" tetrahedrons, measure one inch directly across from each of the four corners and mark with a dot. See picture below:**

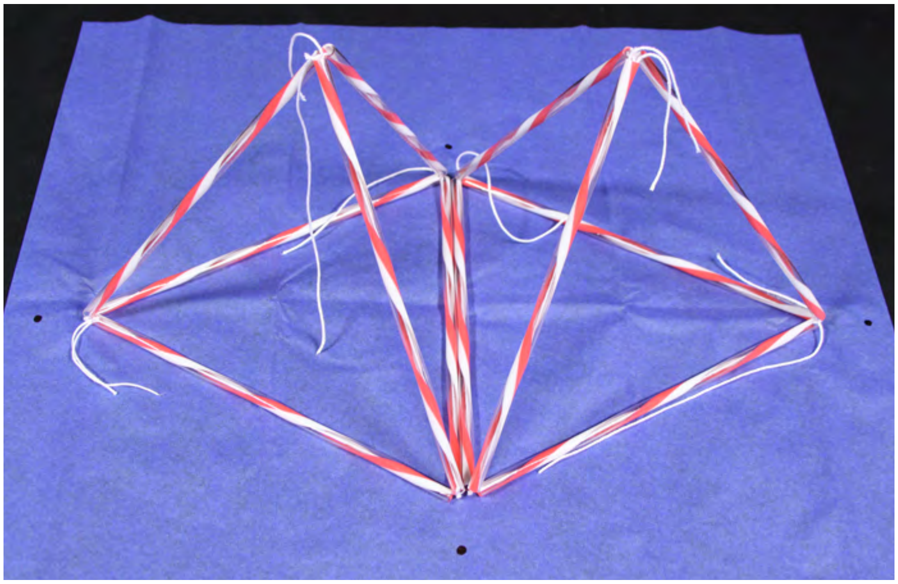


Fig. 7 One-inch marks to create template

4. **Remove the tetrahedrons and connect the dots with a ruler. See picture below:**

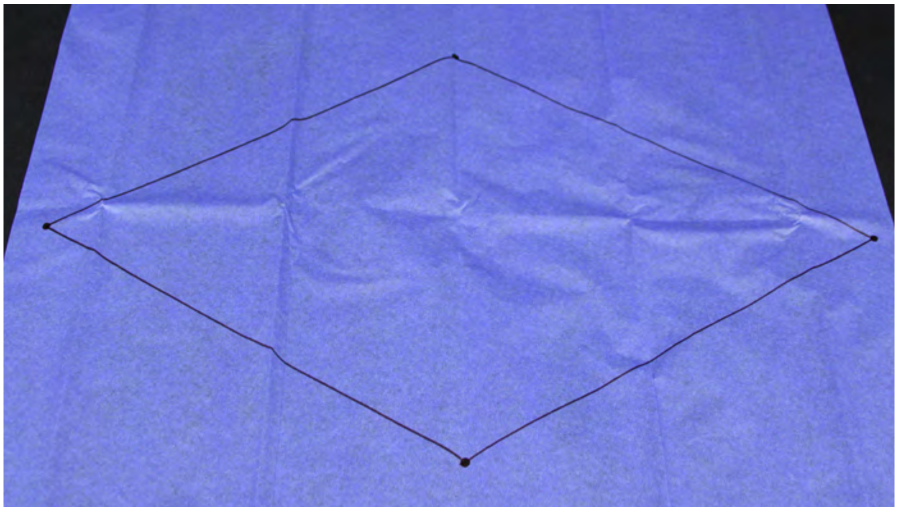


Fig. 8 Template construction

5. **Next, measure two inches directly across from the vertex of one of the obtuse angles (obtuse = > 90 degrees) on the template, and make a mark.**

6. **Place any corner of a tetrahedron on the 2 inch mark so that the straws of the tetrahedron cross over the sides of the template and are equidistant from the vertex. See picture below:**

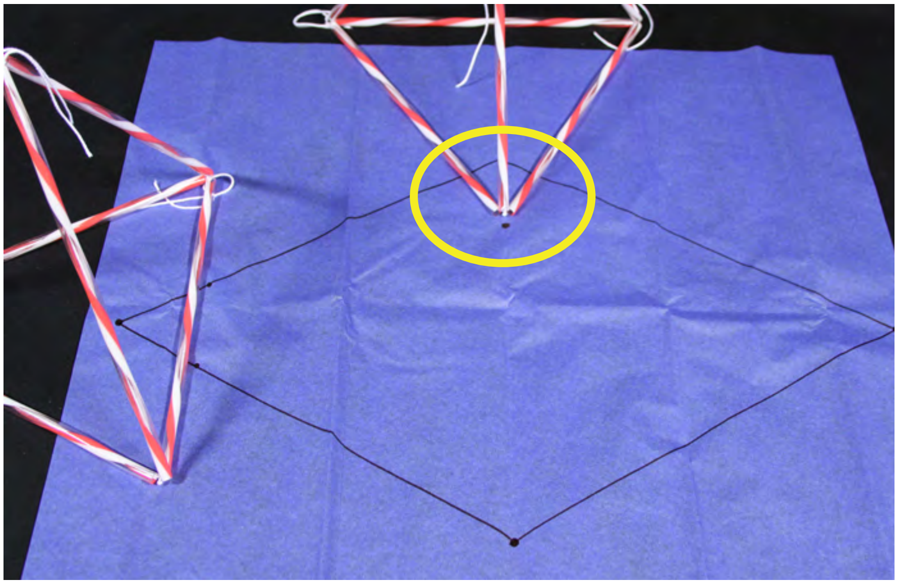


Fig. 9 Obtuse angle marking for template construction

7. **Trace the inside of the side straws from the mark to the sides of the template.**

8. **Follow steps 5 – 7, and do the same to the other obtuse angle of the template.**

9. **Next, measure 1 ½ inches directly across from the vertex of the acute angle (acute = < 90 degrees) on the template, and make a mark.**

10. **Place any side of the tetrahedron on the 1½ inch mark so that the straws of the tetrahedron cross over the sides of the template and are equidistant from the vertex.**

11. **Trace along the side of the straw through the mark to each of the template sides. See picture below (fig. 10):**

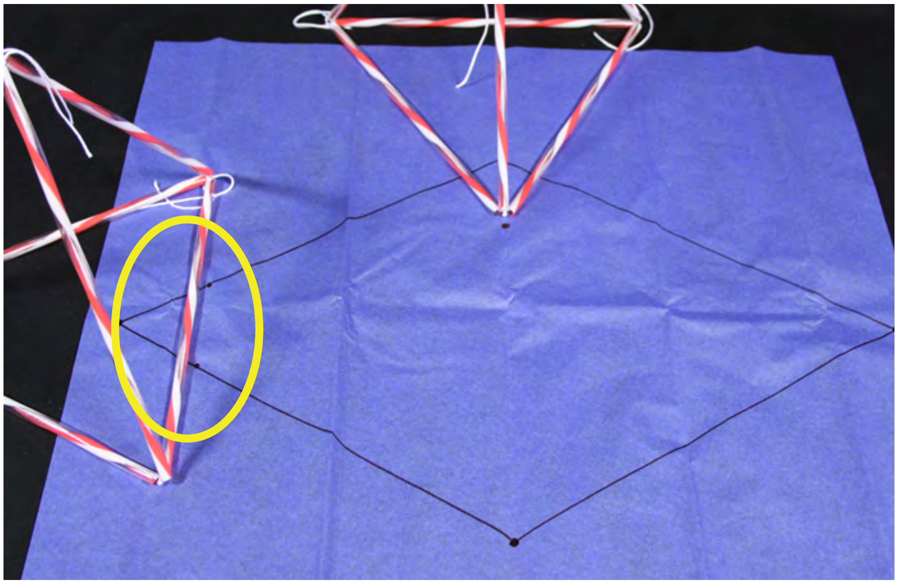


Fig. 10 Acute angle marking for template construction

12. **Follow instructional steps 9 – 11, and do the same to the other acute angle of the template.**

13. **Your completed tissue paper tetrahedron template should look like fig. 11 below:**

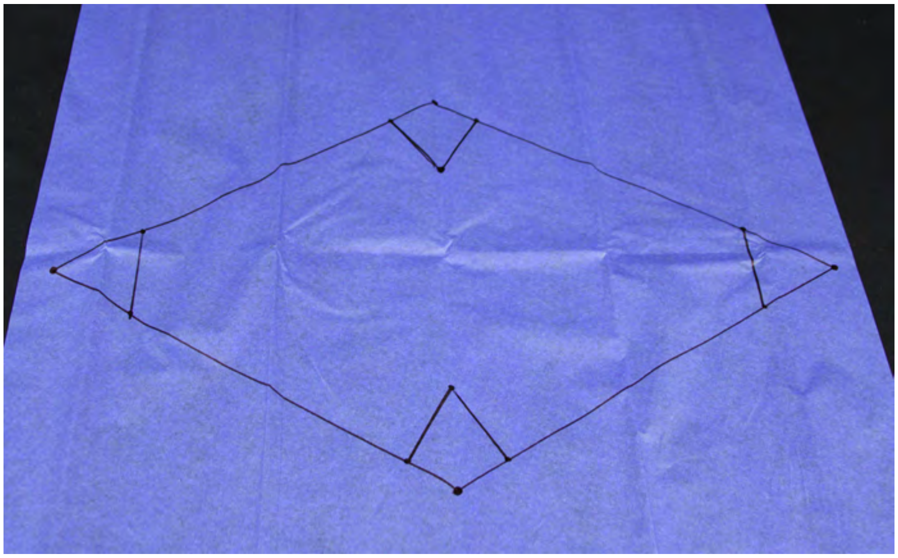


Fig. 11 Tissue paper template

14. **Cut out the entire diamond-shaped template.**

15. **Next, cut out or cut off the traced corners of the template so it looks like the picture below (fig. 12):**

16. **Trace this template onto three sheets of tissue paper in preparation of covering three other tetrahedrons.**

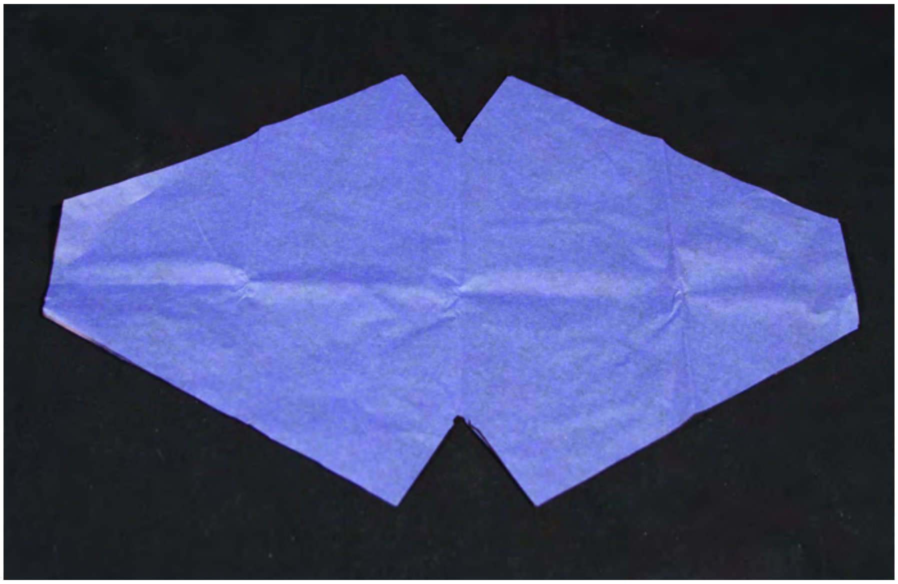


Fig. 12 Completed tissure paper template

Step Five - Cover the Tetrahedron - Read these steps aloud to the class.

1. **Lay the one cut tissue paper template on your table.**

2. **Place one side of the tetrahedron in the middle of the template so there is enough tissue paper to wrap around the other two sides. See picture below (fig. 13):**

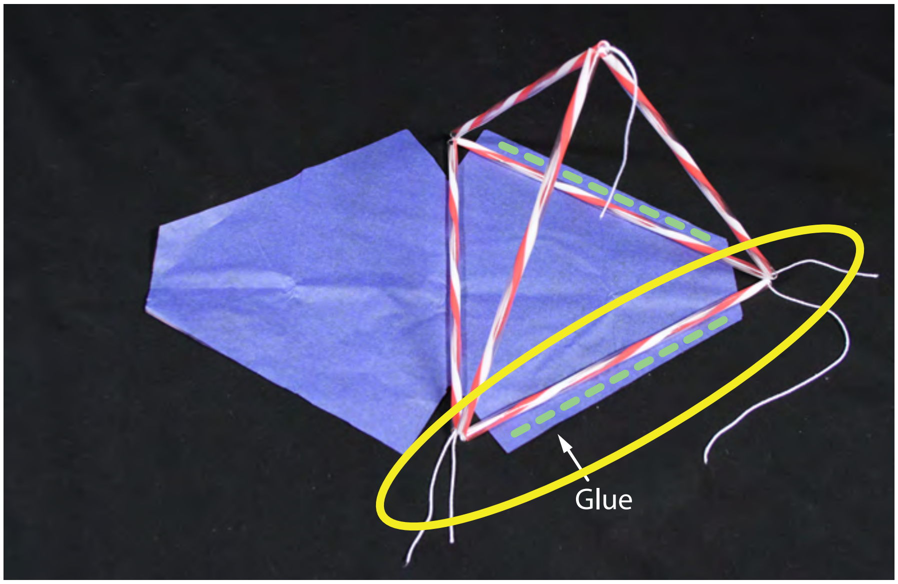


Fig. 13 Placement of tetrahedron on tissue paper template

3. **Now spread the glue along the flaps and fold the flaps over the straws. (See yellow circle in figure 13). Make sure the tissue is wrapped tightly around the straws.**

4. **Flip the tetrahedron onto the other side of the tissue template.**

5. **Now, spread glue onto the flaps.**

6. **Fold these flaps over the straws for a tight fit. See picture below (fig. 14):**

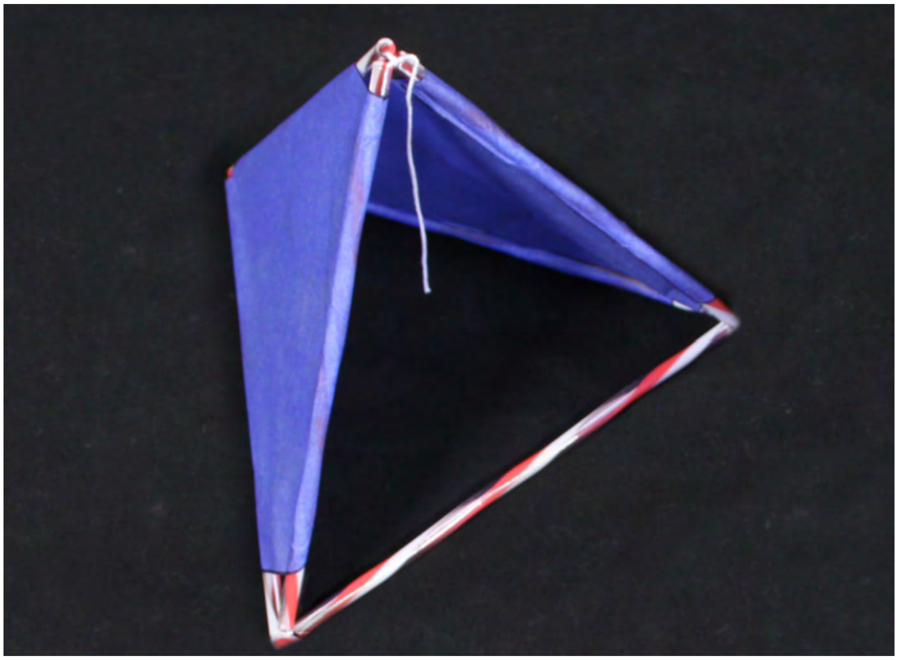


Fig. 14 Covered tetrahedron

Step Six - Add Levels to the Tetrahedron - Read these steps aloud to the class.

1. **Now that you have successfully created and covered two tetrahedrons, you will need to repeat Steps One through Five to make an additional two tetrahedrons (four in total).**

2. **Once you have created the other two remaining tetrahedrons, select three of them and place the tetrahedrons on a flat surface or table to form one large triangle. All sides with the tissue paper should be facing away from you. See picture below (fig.15).**

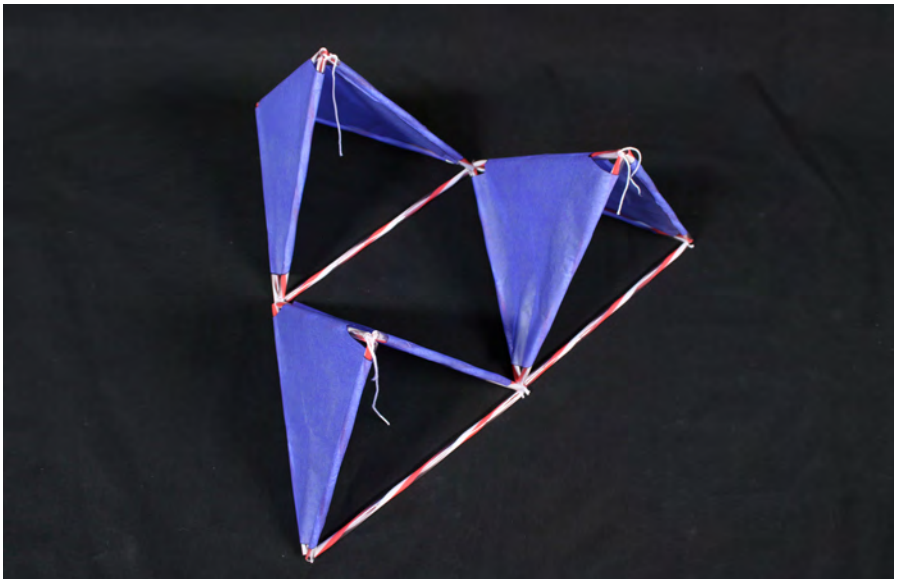


Fig. 15 Three tetrahedrons in the form of one large triangle

3. **Each tetrahedron will have strings that are free. Use those free strings to tie one tetrahedron to another. This will tie the adjacent base vertices together.**

4. **Place the three tied tetrahedrons flat on the table in the same way they were tied together.**

5. **Now, take the fourth tetrahedron and place it on on the top of the three and secure each end. See picture below (fig. 16).**

6. **Be sure to fasten all ends tightly and securely so there is very little wiggle room among the tetrahedrons.**

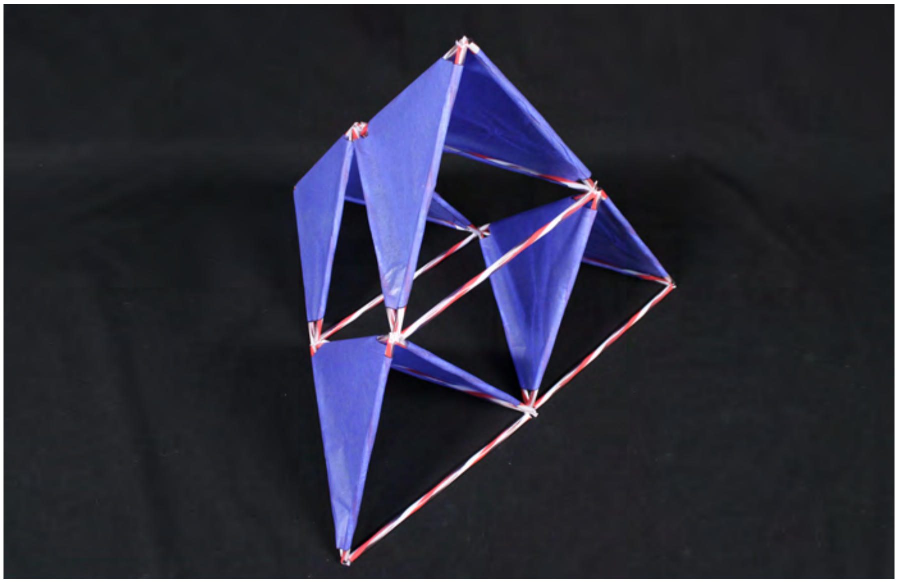


Fig. 16 Four tetrahedrons

7. **As a team, decide how many more tetrahedrons you want to add to your kite before you decide to fly it.** Repeat Step One through Step Five as necessary for your additions. Also, remember that when you add your additional tetrahedrons make sure the connections are tight.

Step Seven - Build Your Bridle - Read these steps aloud to the class.

1. **Now that you have made your kite, you will need to create and attach your bridle in order to fly it.**
2. **Tie a string (approximately 15 feet long) to the ruler so it can serve as your bridle.**
3. **Take your ruler to your teacher and he or she will use the hot glue gun to make sure your string stays on the ruler.**
4. **TEACHER: Take the hot glue gun and insert a glue stick.** Plug the glue gun into the wall giving it time to heat up. Once the glue gun is ready, apply glue (approximately the size of the quarter) to the ruler in order to fasten the string to the bridle. Only when glue has cooled, return the glued ruler and string to the students.
5. **Place your kite on the table with the base touching the table.**
6. **Next, tie a 24-inch string firmly to the very top of the kite.**
7. **Tie the same piece of string again to the middle joint.** This will be between the top section of the kite and the bottom toward the front. There should not be any slack in the string.
8. **Next, tie a loop in the middle of your string.** The loop should be about the size of a quarter.
9. **Now, attach the string of your kite to the loop.**
10. **Your kite is finished and ready to fly.**
11. **Complete the questions on your Kite Engineering Worksheet before attempting to fly your kite.**

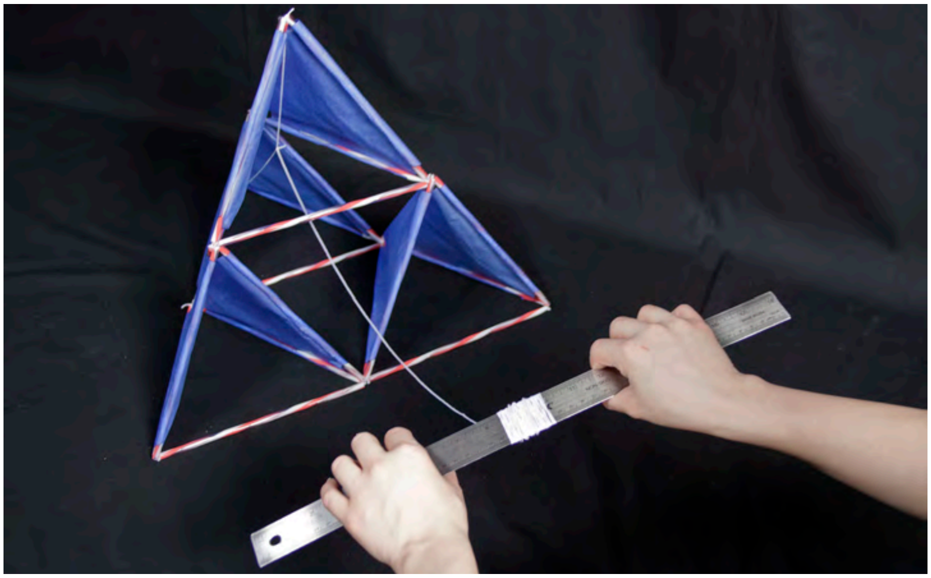


Fig. 17 Completed kite with bridle

NATIONAL SCIENCE STANDARDS 5-8

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

NATIONAL SCIENCE STANDARDS 9-12

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

NATIONAL MATH STANDARDS 5-12

NUMBER AND OPERATIONS

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems
- Understand meanings of operations and how they relate to one another
- Compute fluently and make reasonable estimates

GEOMETRY

- Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships
- Use visualization, spatial reasoning, and geometric modeling to solve problems

MEASUREMENT

- Understand measurable attributes of objects and the units, systems, and processes of measurement
- Apply appropriate techniques, tools, and formulas to determine measurements.

DATA ANALYSIS AND PROBABILITY

- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them

PROCESS

- Problem Solving
- Communication
- Connections
- Representation

Activity 5 — Box Kite Construction 101

GRADES 5-12

Time Requirements: 90 minutes

Materials:

In the Box

None

Provided by User

- Kite Template (1 per student)
- Ruler (1 per student)
- Wood Glue (3-4 bottles enough for 1 class)
- Cellophane Tape (enough for a class 2-3 rolls)
- Translucent 1 ply kitchen trash bag (1 per student)
- Plastic grocery bag (1 per student)
- Black magic marker (1 per student)
- Scissors (1 per student)
- Kite Making Dowels (4 twelve (12 inch) and 2 eight (8 in) per student)
- Electrical Tape (enough for a class 1-2 rolls)
- Yard Stick (2-4 for the class)
- Sandpaper (1 per student)
- Flying Line (1 roll per student)
- Double-sided sticky tape

Worksheets

None

Objective:

Through experimentation, students will:

1. Understand that wind is a force of nature.
2. Explain how wind impacts objects in the air.
3. Use prior knowledge and new information gained through the activity to construct their own box kite.

Activity Overview:

Students will use this activity to build upon further kite building activities by constructing their own basic box kite. By following the directions and using the materials provided, students will create and fly their box kite.

Activity:

Part One - Constructing the Kite Sail

You will need the following supplies to complete this portion of the activity:

- 4 (12 inch) kite dowels
- Kite Template (2 pages)
- Scissors
- Ruler
- Black magic marker
- Translucent kitchen or recyclable trash bag (single ply/1-ply)
- Tape

1. **Cut out Sections #1, #2 and #3 of the Kite Template. (Figure 18).**

2. **Lay Sections #1, #2 and #3 of the Kite Template on a flat surface and tape the bottom of Section #1 to the top of Section #2 and the bottom of Section 2 to the top of Section 3.** Laid flat, this template represents one cell of the kite. (You will need two cells.)

3. **Cut the translucent trash bag so it opens into a single layer and lay it flat on the table.**

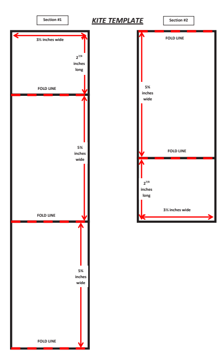


Fig. 18 Kite Template

MUSEUM IN A BOX

Reference Materials

Kite Template (Figure 18)

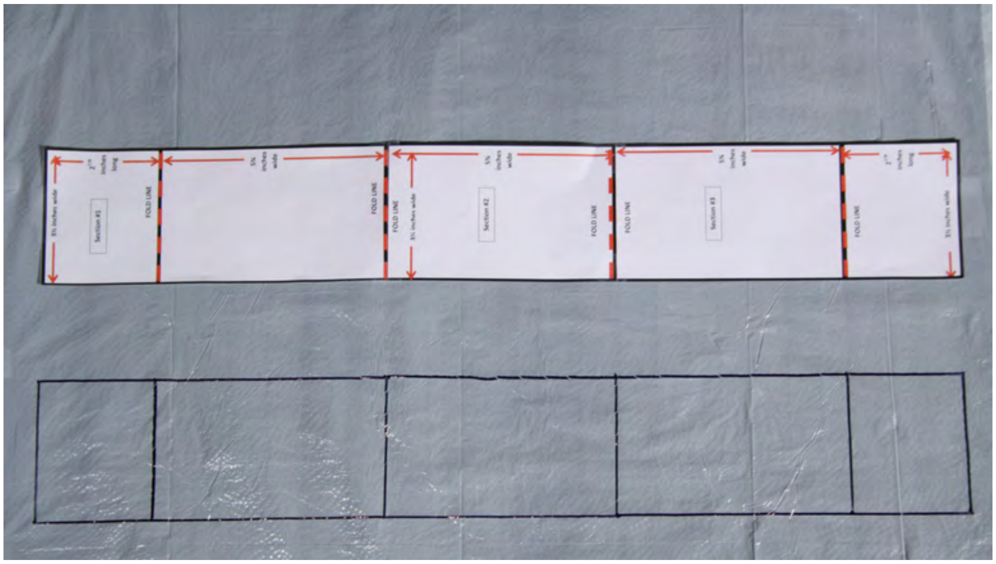
Key Terms:

None

4. **Place the Box Kite Template (Sections #1, #2 and #3) on top of the trash bag with enough room to trace a second one.**

5. **Trace the outline of template.** Be sure you are making a mark where the four (4) fold lines are located at the top and bottom of the template.

6. **Place your ruler on the four sets of top and bottom marks, and connect the marks to identify the four fold lines. (See picture below.)**

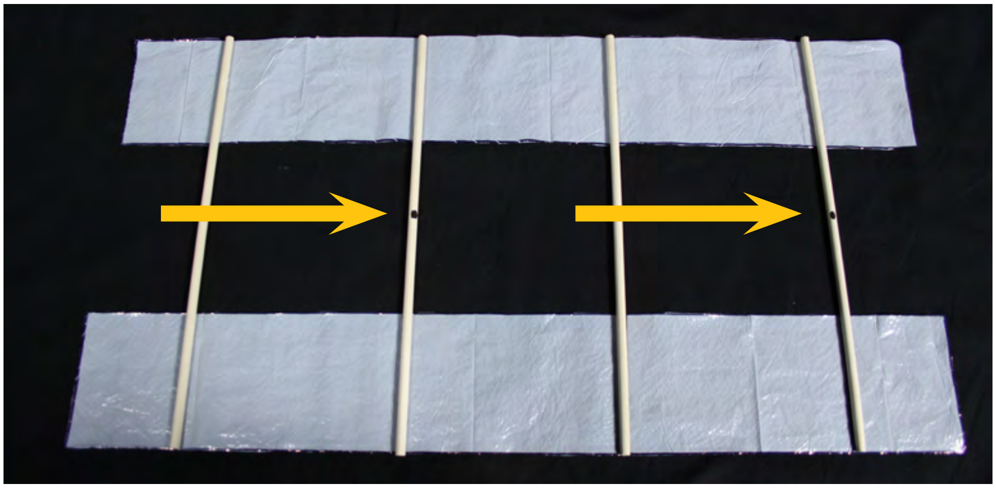


7. **Repeat steps 4, 5 and 6 to trace a second Box Kite cell.**

8. **Cut out the two cells from the trash bag and lay them marked-side up on the table one above the other with the fold-lines aligned.**

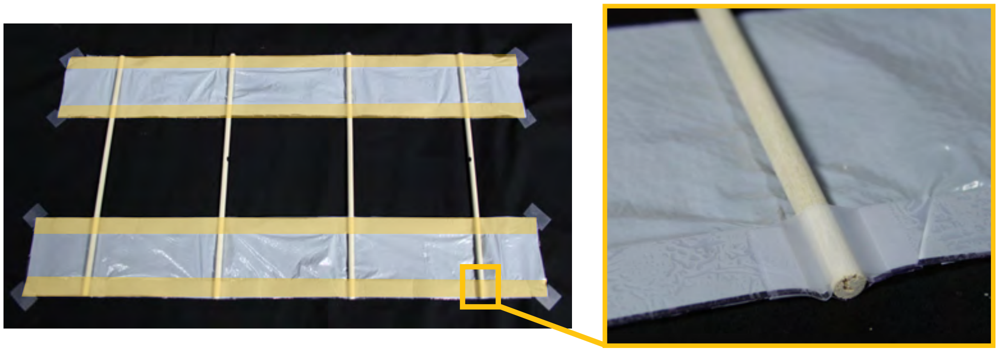
9. **Take your 4 twelve-inch kite dowels and place them across both templates on the drawn fold-lines.** Position the cells so that the 12-dowels' ends are at the top and bottom edges.

10. **With your marker, measure the 2nd dowel and 4th dowels at 6 inches and make a dot. (See picture below.)**



11. **Take 4 small pieces of tape and tape down each corner (8) of both cell templates securing it to the table. (See picture below.)**

12. **Make sure your kite dowels are in place.** Take a roll of tape and release a few inches of tape. DO NOT CUT the tape. Place the tape on the bottom template along the bottom edge starting at the very left of the template.
13. **Very slowly pull more tape out while pressing down the tape onto the template.**
14. **Extend the tape and press down from left to right on the template, making sure the tape goes securely over each kite dowel.**
15. **Once you reach the end of the template cut the piece of tape and secure it to the right end of the bottom template.**
16. **Go back over the long piece of tape from left to right and smooth with your fingers.**

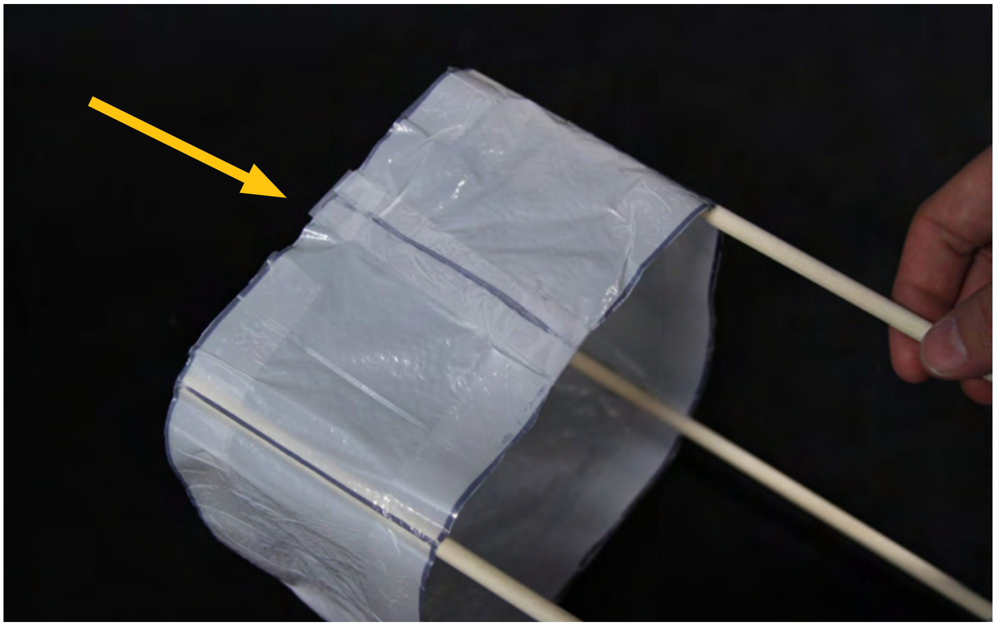


17. **Repeat steps 12 thru 16 for the other three edges of cell templates.**
18. **Remove everything from your table except the kite template you just finished making.** Gently remove the 4 pieces of tape on the corners of each template. If you are having trouble removing them cut each edge of the piece of tape off.

19. **Take the left end of the kite and gently pull it towards the right side.**

20. **Secure the outside of the two outer edges with a long piece of tape bringing the two joints together.**

21. **Measure another piece of tape similar to the one you just applied and tape the inside of the kite at the two joints.** Both sides should have tape along them and be secured.



Part Two - Constructing the Cross Pieces
You will need the following supplies to complete Part Two and Three of the activity:

- Kite dowels
- Scissors
- Ruler
- Black magic marker
- Electrical tape
- Cellophane tape
- Sandpaper
- Wood glue
- Fly line
- Plastic garbage bag for tail

1. **Take a kite dowel and measure it to 8 inches in length.** Mark that spot on your kite dowel with your marker.

2. **Take your scissors and gently cut your dowel at the 8 inch mark.**

3. **Take your piece of sandpaper and gently smooth the end that was cut but be sure not to sand off enough to affect the length.**

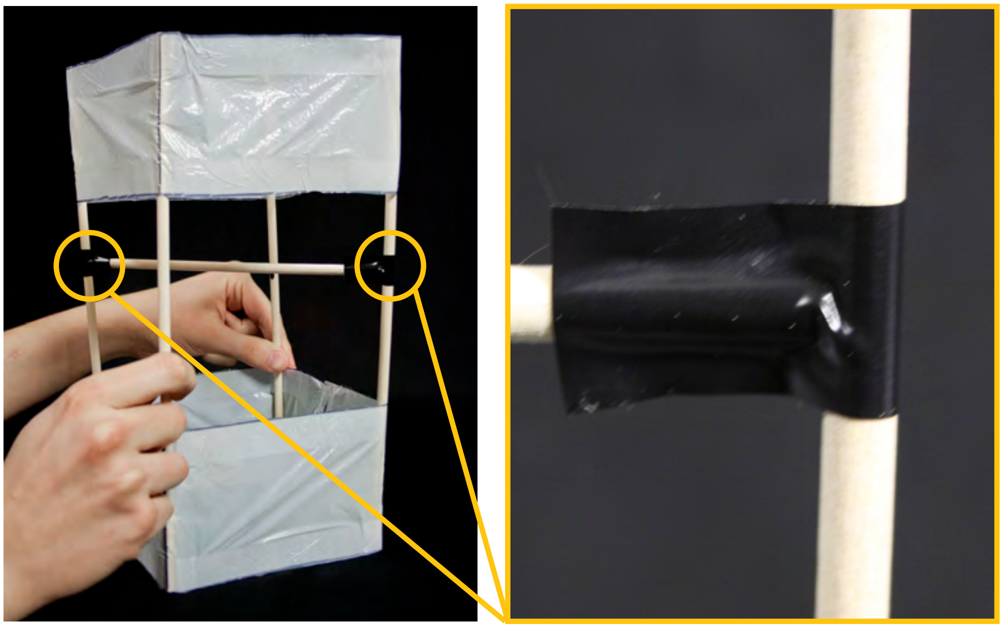
4. **Take another kite dowel and measure it to 8 inches in length.** Mark that spot on your kite dowel with your marker.

5. **Take your scissors and gently cut your dowel at the 8 inch mark.**

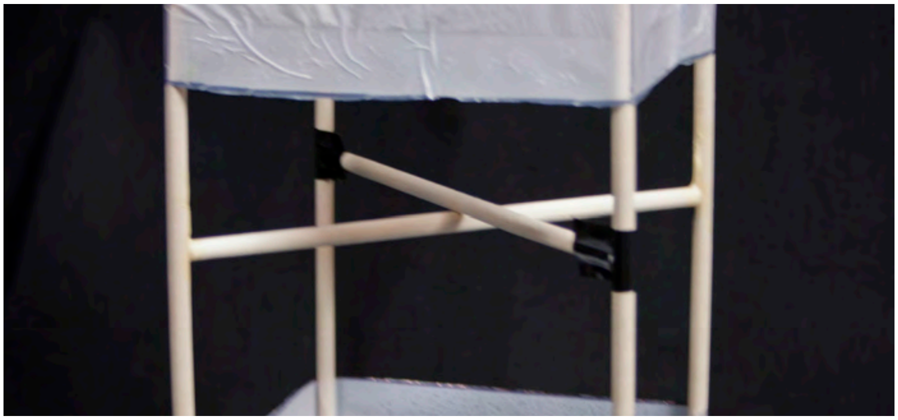
6. **Take your piece of sandpaper and gently smooth the end that was cut but be sure not to sand enough off to affect the length.**

7. **Fit one 8 inch cross-piece between your unmarked kite dowels.**

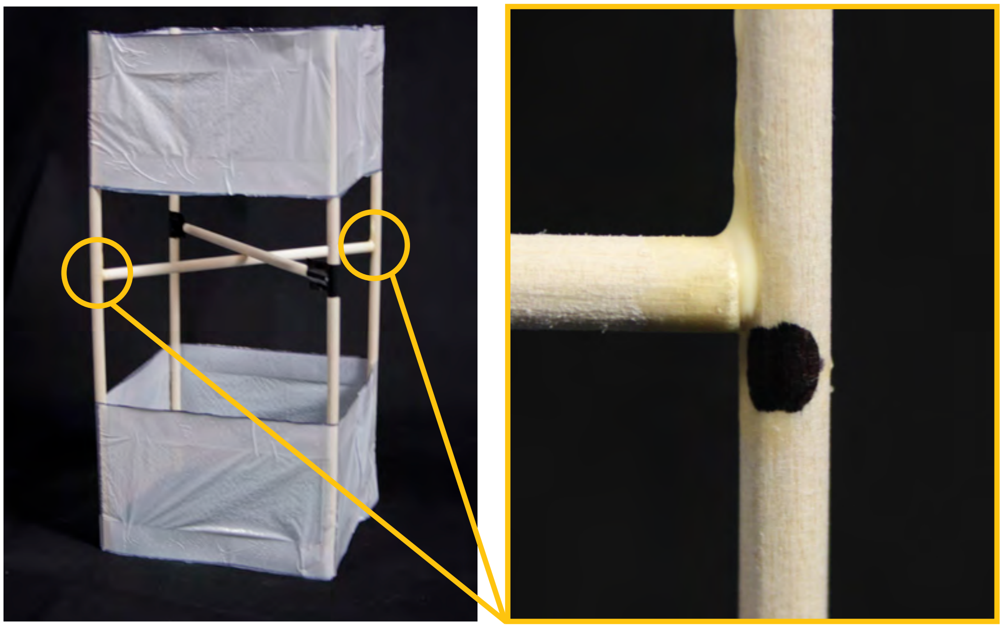
8. **Take a small piece of electrical tape and wrap it around where each tip touches the kite dowel or spar.**



9. **Take the other 8 inch cross-piece and fit it between the two marked kite dowels.** Note that you may need to gently cut and sand the top of your kite dowel little by little until it fits.



10. **Put 2 drops of wood glue at each end to secure it.** Let the wood glue dry. This will take a few minutes. Now the 2 cross-pieces should be holding the kite open. Each plastic kite cell should show a little tension.

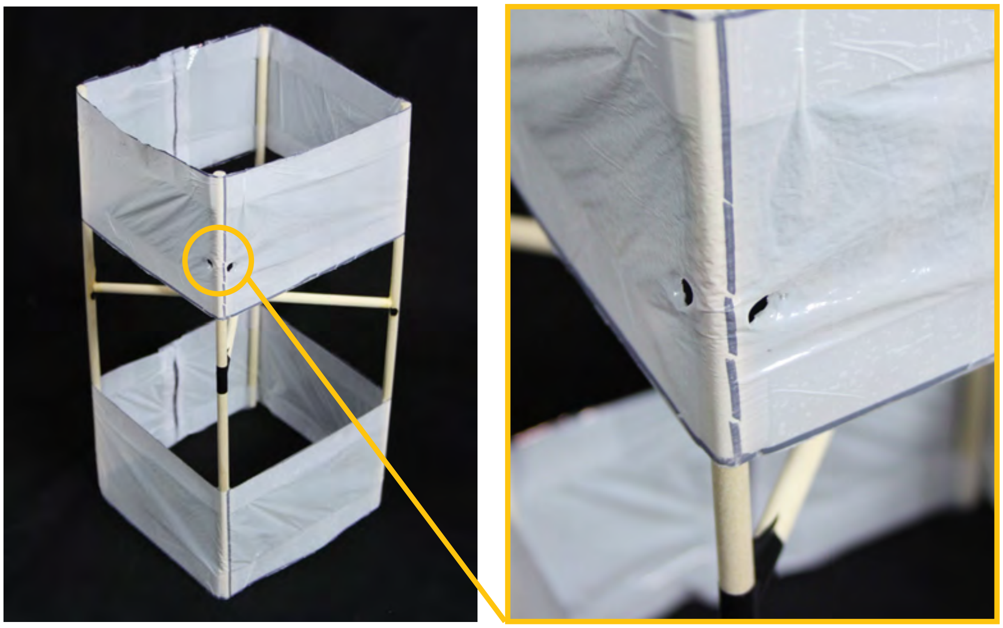


11. **When the glue has dried gently flip your kite over, peel back the tape, and add more wood glue to strengthen the joints on the other side.**

Part Three - Attaching the Kite Sail

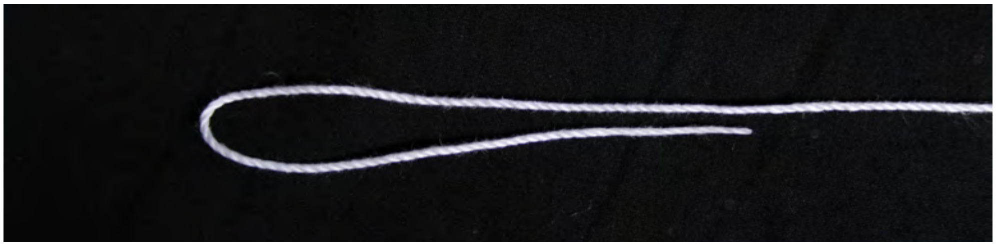
1. **Find one of your unmarked dowels.** Take your ruler and measure on the left and right side of one unmarked dowel 2¼ inches from the top. Mark a dot on each side with your marker.

2. **Take a sharpened pencil and poke a hole into the marked dots on both sides of the kite dowel.**

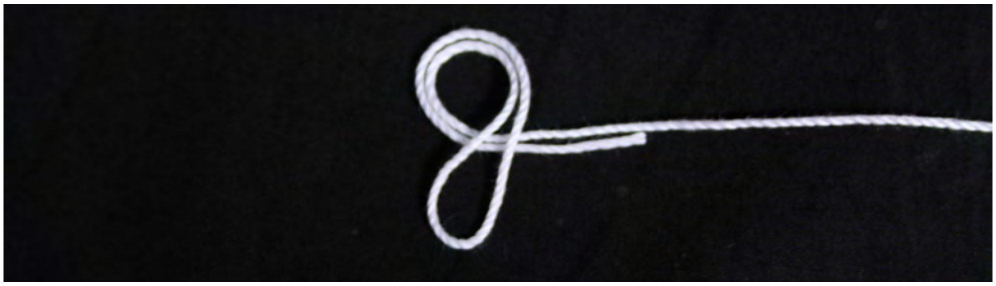


3. Measure and cut a 12 inch piece of flying line.

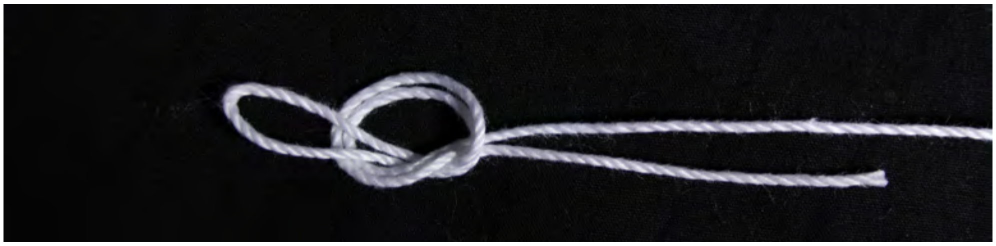
4. Form a loop.



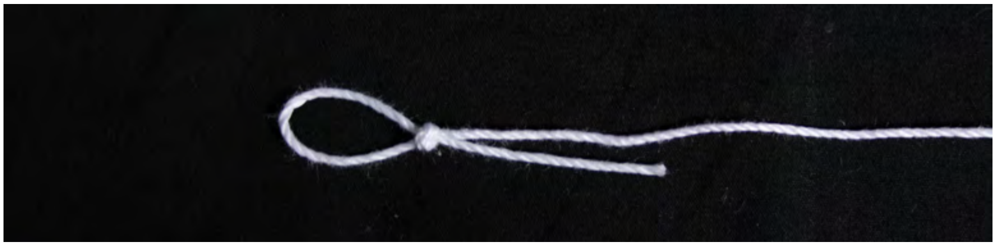
5. Take the "u" shaped part of the line and bring it around and over.



6. Now bring the "u" shaped part of the line under and through.



7. Pull the string tightly.

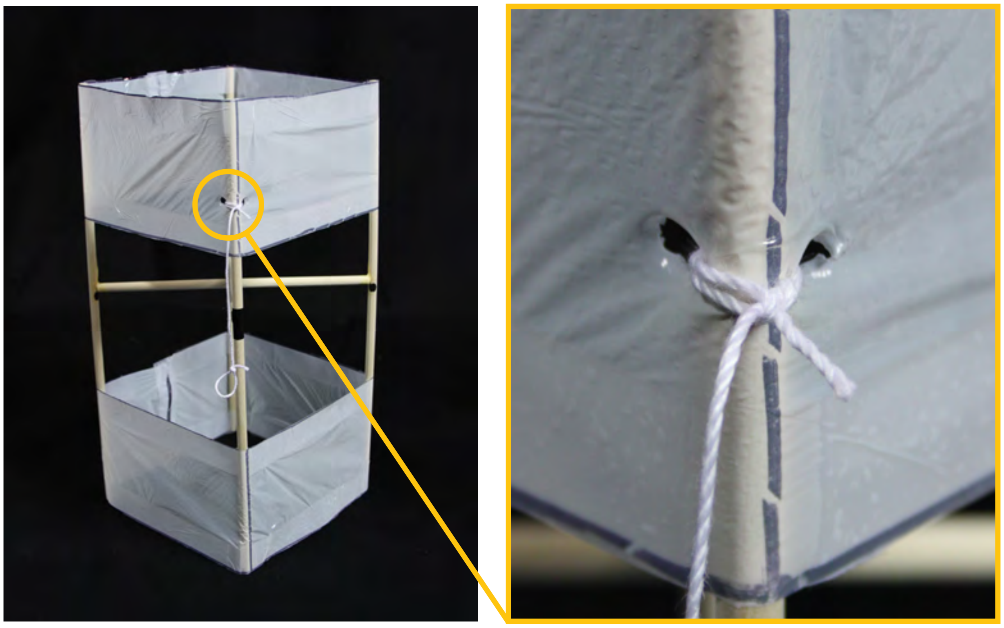


8. Make sure the loop is near one end of the string.

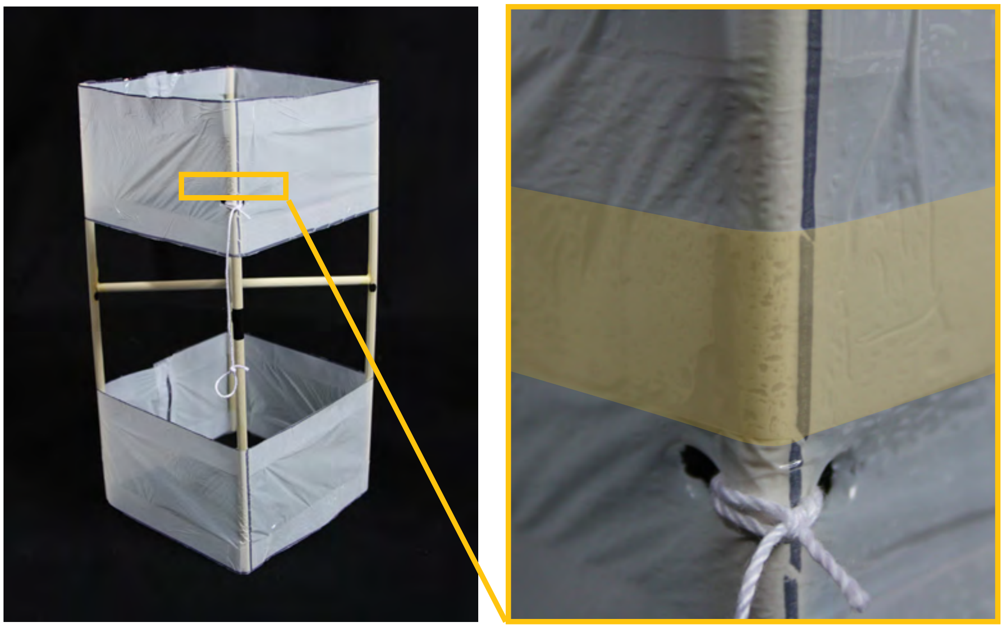
9. Repeat steps 4 through 7 to form another loop.

10. There should now be 2 loops, one near each end of the string.

11. **Attach one end of the double looped-string to the kite by passing it through the hole on the left, around the back of the dowel, and out the other hole on the right hand side.** Now take the string and run it through the first loop. Pull the string tight.

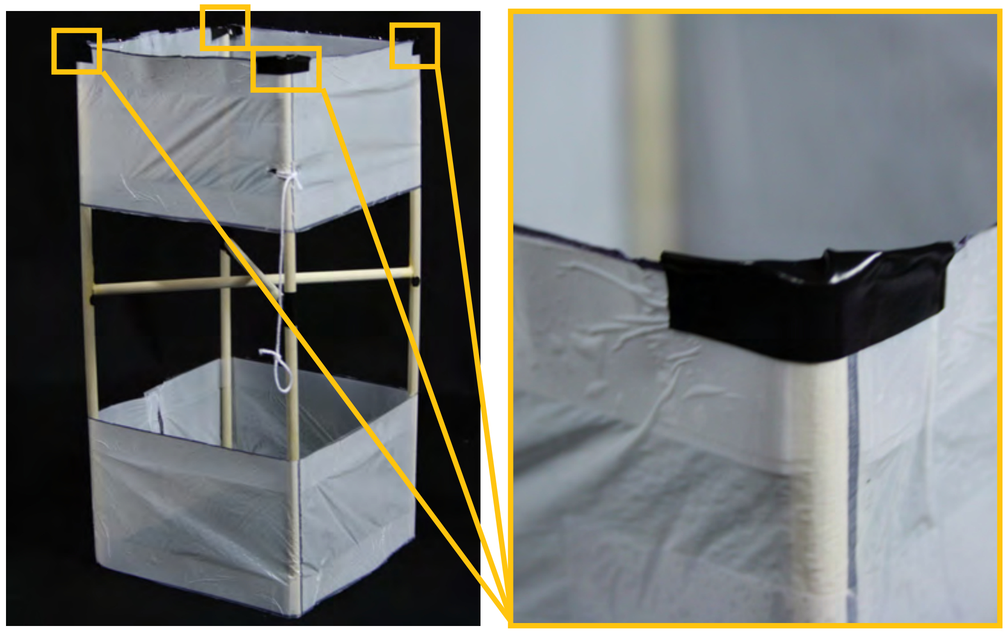


12. **Cut a piece of 3-inch tape and wrap it around the sail, left to right, just above the holes where you put the string.** (See picture below.)



13. **Cut 4 pieces of electrical tape measuring 1 inch a piece.**

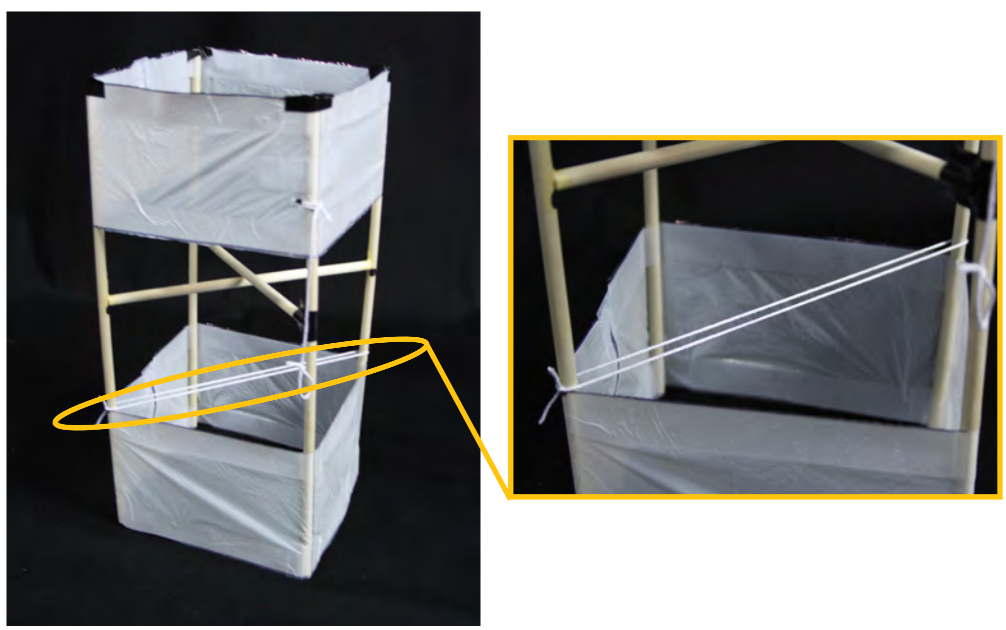
14. **Place 1 piece of tape over each dowel and cap each dowel. (See picture below.)**



15. **Cut another piece of fishing line measuring 12 inches in length.**

16. **Loop the string around the 2 marked dowels. Pull the string so that the string is straight and tie it off. This is called the tensioner.**

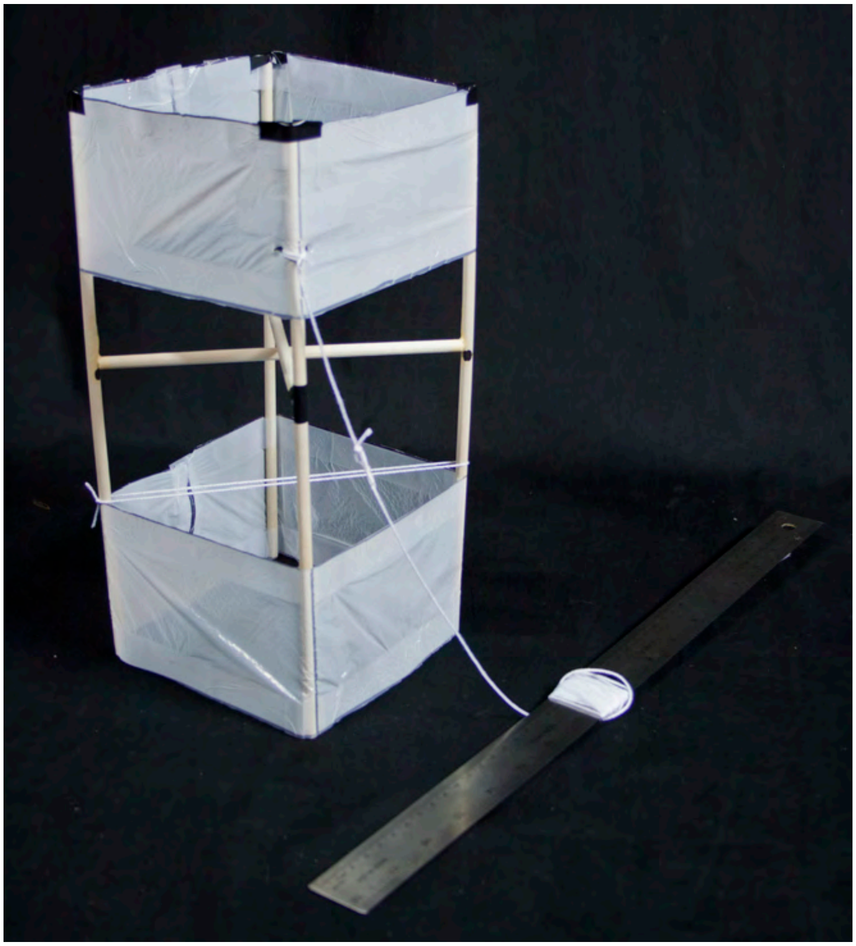
17. **Dab 2 drops of wood glue on the tensioner knot. (See picture below.)**



18. **Finally dab a few drops of glue in the center of the kite where the cross-pieces touch each other.**

Part Four - Attaching the Kite Bridle

1. **Measure a length of flying line approximately 60 feet long.**
2. **Attach the flying line to the bridle. (See picture below.)**
3. **Take the other end of the string and tie it around a ruler.**
4. **Wrap the string around the ruler one more time and secure on the back of the ruler with a 3 inch piece of electrical tape.**
5. **Now gently wrap the string tightly around the ruler until only about 3-5 feet are left between the kite and ruler. (See picture below.)**



Part Four - Attaching the Kite Tail (Optional)

1. **Cut off several loops of a closed, flat plastic grocery bag (or cut plastic strips from leftovers from kite cells).** Loops or strips are approximately 2 inches or more in width.

2. **Tie the loops or strips together to create a tail approximately 35 inches in length.**

3. **Lay a piece of double-sided sticky tape along the dowel that has the bridle attached, and press the tail securely on the dowel and sail.**
   NOTE: If the kite loops around in one direction, add more tail loops to one side of the lower cell.

NATIONAL SCIENCE STANDARDS 5-8

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

NATIONAL SCIENCE STANDARDS 9-12

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

EARTH AND SPACE

- Energy in the earth system

SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

Reference Materials

Glossary

Apex:
The tip or point of an object.

Base:
The foundation of an object.

Edge:
A line where two surfaces of a solid meet.

Equilateral:
All sides of an object are equal.

Equilateral Triangle:
A triangle that has three equal sides and angles.

Face:
A flat surface of a 3-dimensional object.

Parallelogram:
A quadrilateral that has both pairs of opposites sides parallel to each other.

Platonic Solid:
Classified as one of the five regular polyhedrons including the tetrahedron, octahedron, hexahedron, icosahedrons, and dodecahedron.

Pyramid:
A solid geometric shape that has a polygonal base and triangular sides that meet in a singular point.

Quadrilateral:
A plane figure that has four sides and four angles otherwise known as a polygon that has four sides.

Rhombus:
An angled equilateral parallelogram.

Triangle:
A closed plane figure that has three sides and three angles.

Triangular Numbers:
The number of dots, mathematically represented by "*n*", in an equilateral triangle evenly filled with dots; the successive sums of the first *n* natural numbers 1, 3, 6, 10, 15, … representable by dots arranged in triangles.

Tetrahedron:
A solid triangular pyramid or a geometric shape comprised of four plane faces.

Vertex:
A point in a geometrical solid that is common to three or more sides.

Vertices:
Plural of vertex.

SUGGESTED ADDITIONAL READINGS:

None

SUGGESTED INTERNET SEARCHES:

Kites

History of Kites

Chinese Fishing Kites

Wright Brothers and Kites

Alexander Graham Bell's Tetrahedron Kite

Benjamin Franklin and Kite Experiment

How Kites are Used to Generate Energy

Beaufort Wind Scale

Future of Kites

Uses of Kites Today

Energy Producing Kites

Fig. 1 The Beaufort Scale

Beaufort number	Description	Wind speed	Wave height	Sea conditions	Land conditions
0	Calm	< 1 km/h (< 0.3 m/s) < 1 mph < 1 kn < 0.3 m/s	0 m 0 ft	Flat.	Calm. Smoke rises vertically.
1	Light air	1.1–5.5 km/h (0.3-2 m/s) 1–3 mph 1–2 kn 0.3–1.5 m/s	0–0.2 m 0–1 ft	Ripples without crests.	Smoke drift indicates wind direction and wind vanes cease moving.
2	Light breeze	5.6–11 km/h (2-3 m/s) 4–7 mph 3–6 kn 1.6–3.4 m/s	0.2–0.5 m 1–2 ft	Small wavelets. Crests of glassy appearance, not breaking.	Wind felt on exposed skin. Leaves rustle and wind vanes begin to move.
3	Gentle breeze	12–19 km/h (3-5 m/s) 8–12 mph 7–10 kn 3.4–5.4 m/s	0.5–1 m 2–3.5 ft	Large wavelets. Crests begin to break; scattered whitecaps.	Leaves and small twigs constantly moving, light flags extended.
4	Moderate breeze	20–28 km/h (6-8 m/s) 13–17 mph 11–15 kn 5.5–7.9 m/s	1–2 m 3.5–6 ft	Small waves with breaking crests. Fairly frequent whitecaps.	Dust and loose paper raised. Small branches begin to move.
5	Fresh breeze	29–38 km/h (8.1-10.6 m/s) 18–24 mph 16–20 kn 6 8.0–10.7 m/s	2–3 m 6–9 ft	Moderate waves of some length. Many whitecaps. Small amounts of spray.	Branches of a moderate size move. Small trees in leaf begin to sway.
6	Strong breeze	39–49 km/h (10.8-13.6 m/s) 25–30 mph 21–26 kn 10.8–13.8 m/s	3–4 m 9–13 ft	Long waves begin to form. White foam crests are very frequent. Some airborne spray is present.	Large branches in motion. Whistling heard in overhead wires. Umbrella use becomes difficult. Empty plastic garbage cans tip over.

Fig. 1 The Beaufort Scale (cont.)

Beaufort number	Description	Wind speed	Wave height	Sea conditions	Land conditions
7	High wind, Moderate gale, Near gale	50–61 km/h (13.9-16.9 m/s) 31–38 mph 27–33 kn 13.9–17.1 m/s	4–5.5 m 13–19 ft	Sea heaps up. Some foam from breaking waves is blown into streaks along wind direction. Moderate amounts of airborne spray.	Whole trees in motion. Effort needed to walk against the wind.
8	Gale, Fresh gale	62–74 km/h (17.2-20.6 m/s) 39–46 mph 34–40 kn 17.2–20.7 m/s	5.5–7.5 m 18–25 ft	Moderately high waves with breaking crests forming spindrift. Well-marked streaks of foam are blown along wind direction. Considerable airborne spray.	Some twigs broken from trees. Cars veer on road. Progress on foot is seriously impeded.
9	Strong gale	75–88 km/h (20.8-24.4 m/s) 47–54 mph 41–47 kn 20.8–24.4 m/s	7–10 m 23–32 ft	High waves whose crests sometimes roll over. Dense foam is blown along wind direction. Large amounts of airborne spray may begin to reduce visibility.	Some branches break off trees, and some small trees blow over. Construction/temporary signs and barricades blow over.
10	Storm Whole gale	89–102 km/h (24.7-28.3 m/s) 55–63 mph 48–55 kn 24.5–28.4 m/s	9–12.5 m 29–41 ft	Very high waves with overhanging crests. Large patches of foam from wave crests give the sea a white appearance. Considerable tumbling of waves with heavy impact. Large amounts of airborne spray reduce visibility.	Trees are broken off or uprooted, saplings bent and deformed. Poorly attached asphalt shingles and shingles in poor condition peel off roofs.
11	Violent storm	103–117 km/h (28.6-32.5 m/s) 64–72 mph 56–63 kn 28.5–32.6 m/s	11.5–16 m 37–52 ft	Exceptionally high waves. Very large patches of foam, driven before the wind, cover much of the sea surface. Very large amounts of airborne spray severely reduce visibility.	Widespread damage to vegetation. Many roofing surfaces are damaged; asphalt tiles that have curled up and/or fractured due to age may break away completely.
12	Hurricane force	≥ 118 km/h (≥ 32.8 m/s) ≥ 73 mph ≥ 64 kn ≥ 32.7 m/s	≥ 14 m ≥ 46 ft	Huge waves. Sea is completely white with foam and spray. Air is filled with driving spray, greatly reducing visibility.	Very widespread damage to vegetation. Some windows may break; mobile homes and poorly constructed sheds and barns are damaged. Debris may be hurled about.

Fig. 2 Triangle

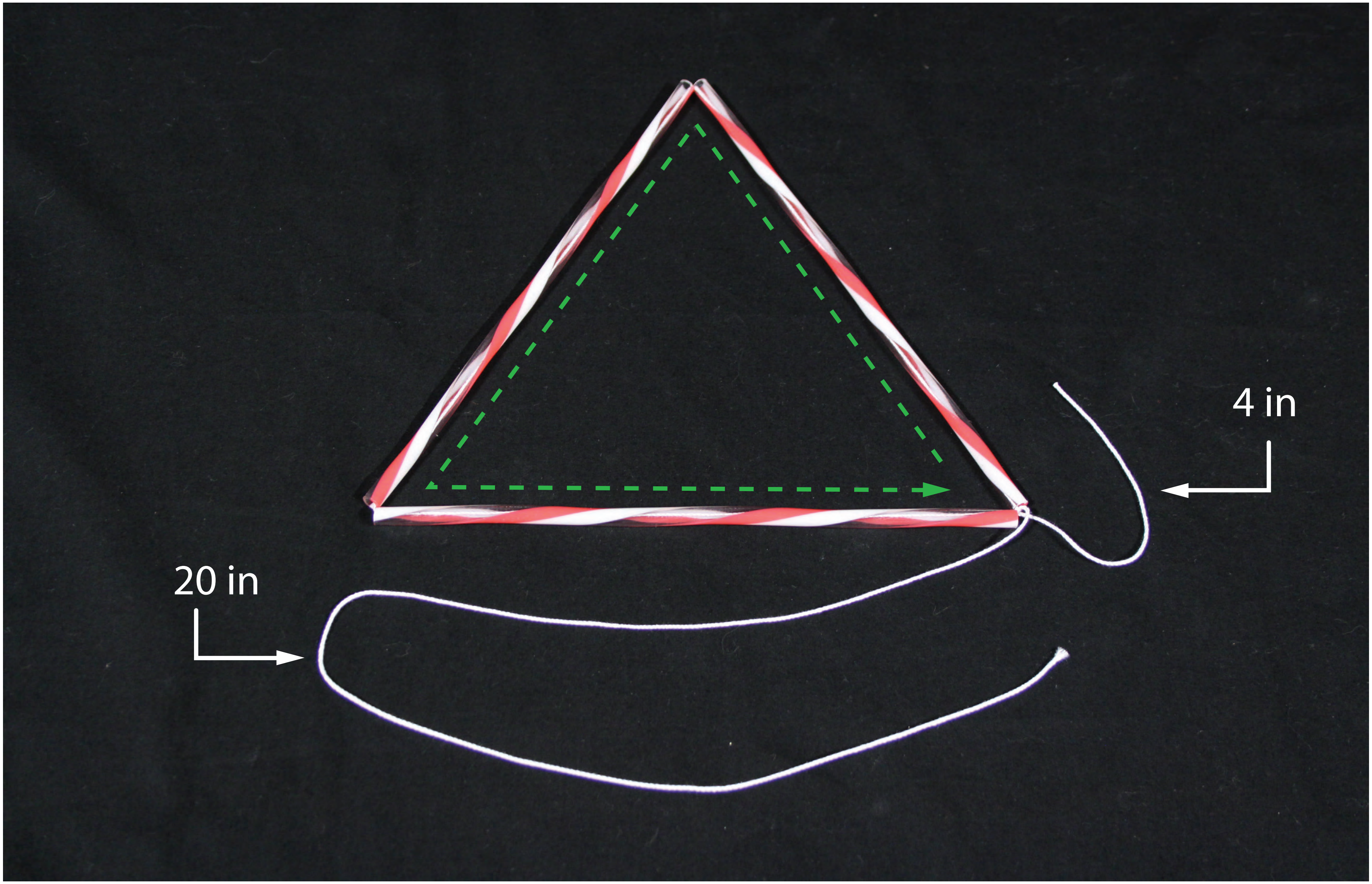


Fig. 3 Rhombus construction

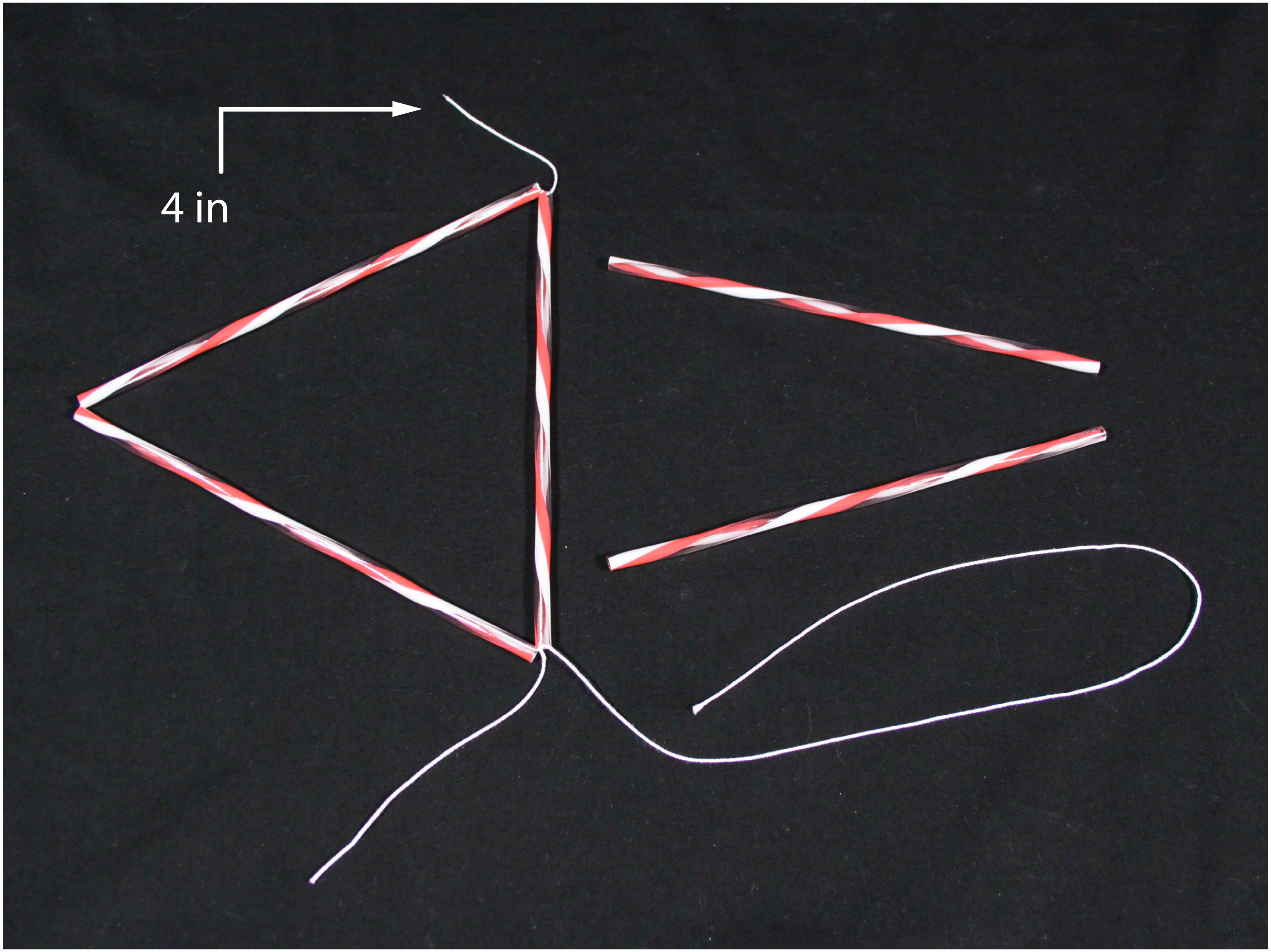


Fig. 4 Completed rhombus

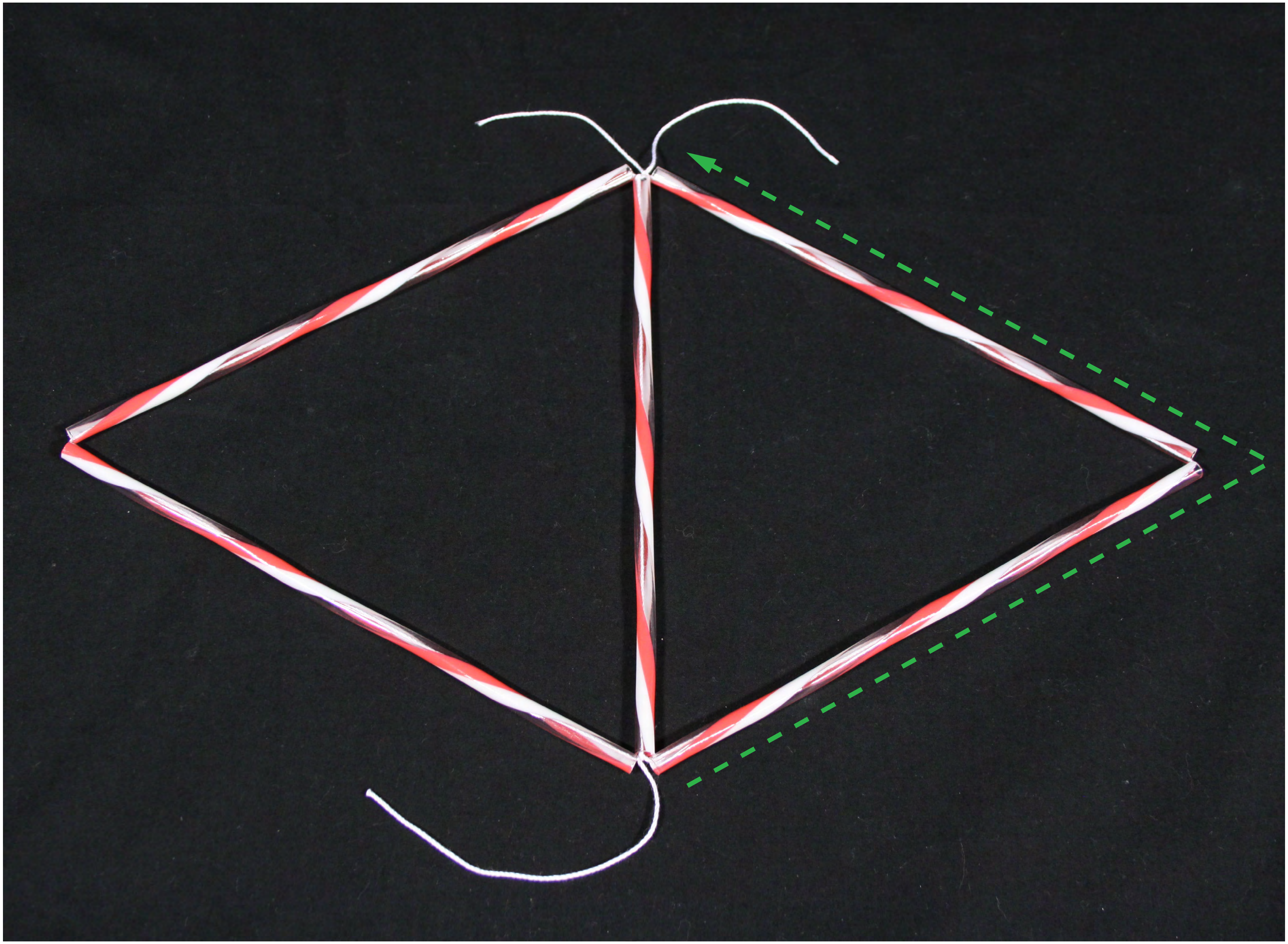


Fig. 5 Three dimensional tetrahedron construction

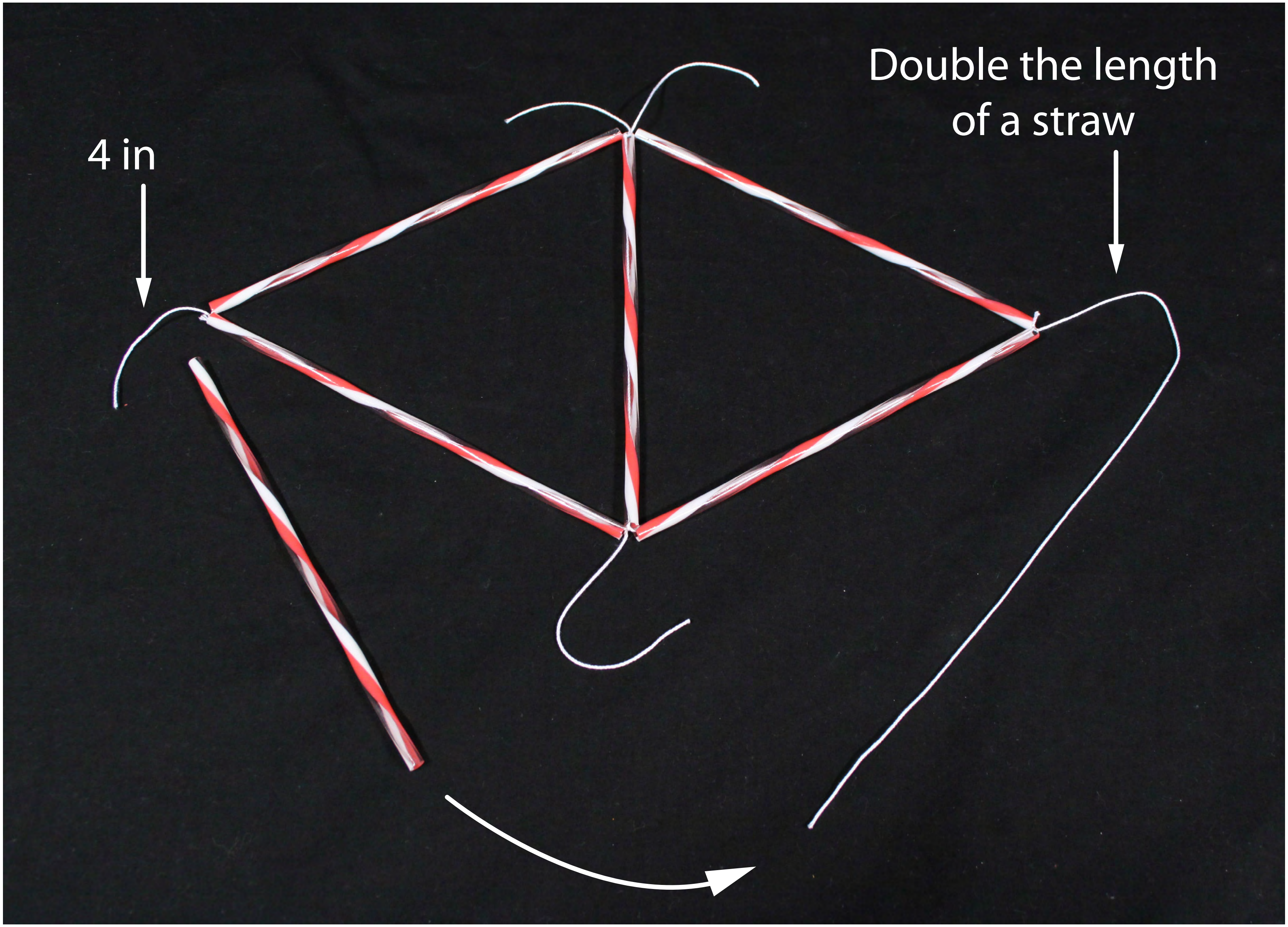


Fig. 6 Completed three dimensional tetrahedron

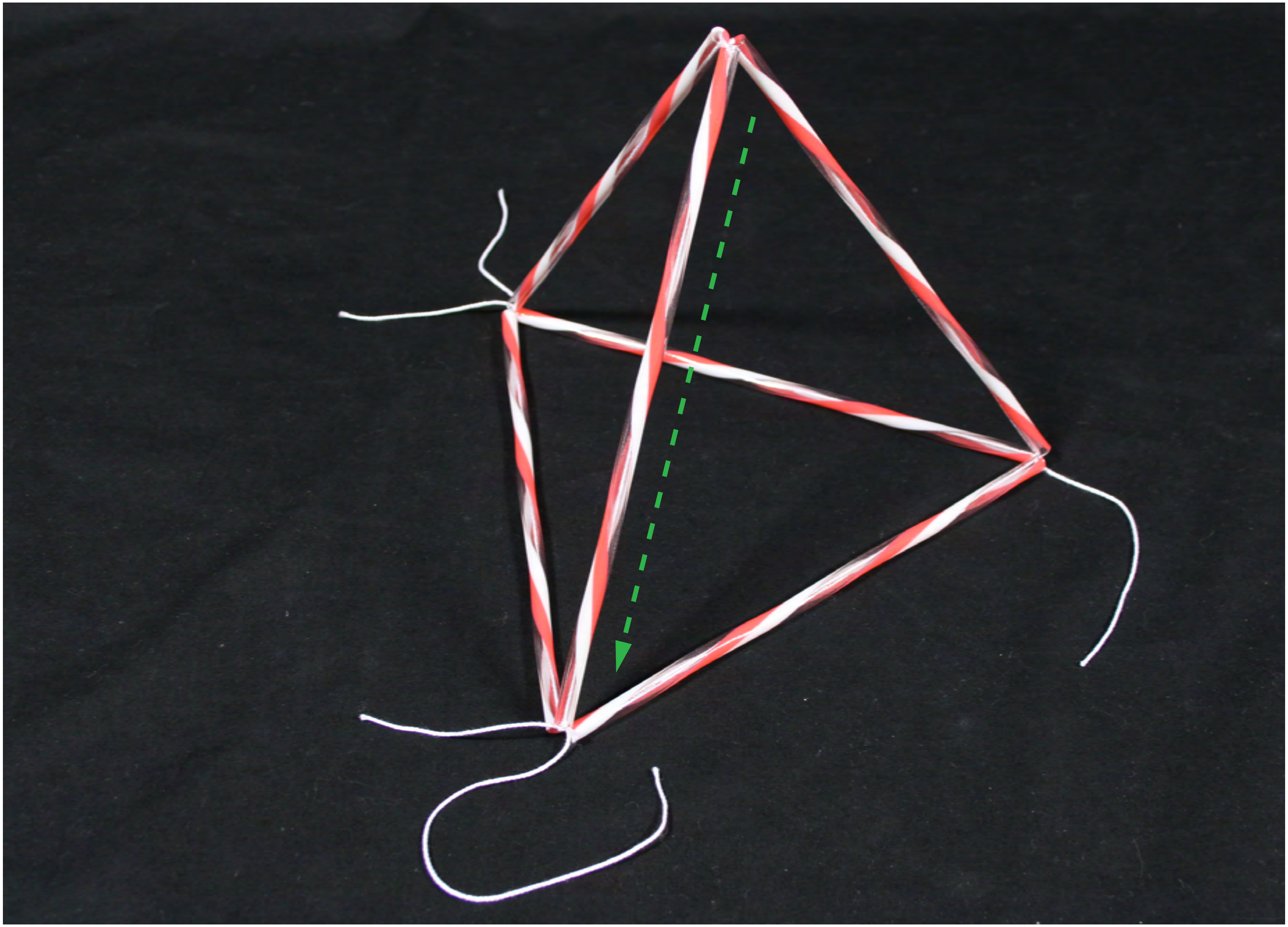


Fig. 7 One-inch marks to create template

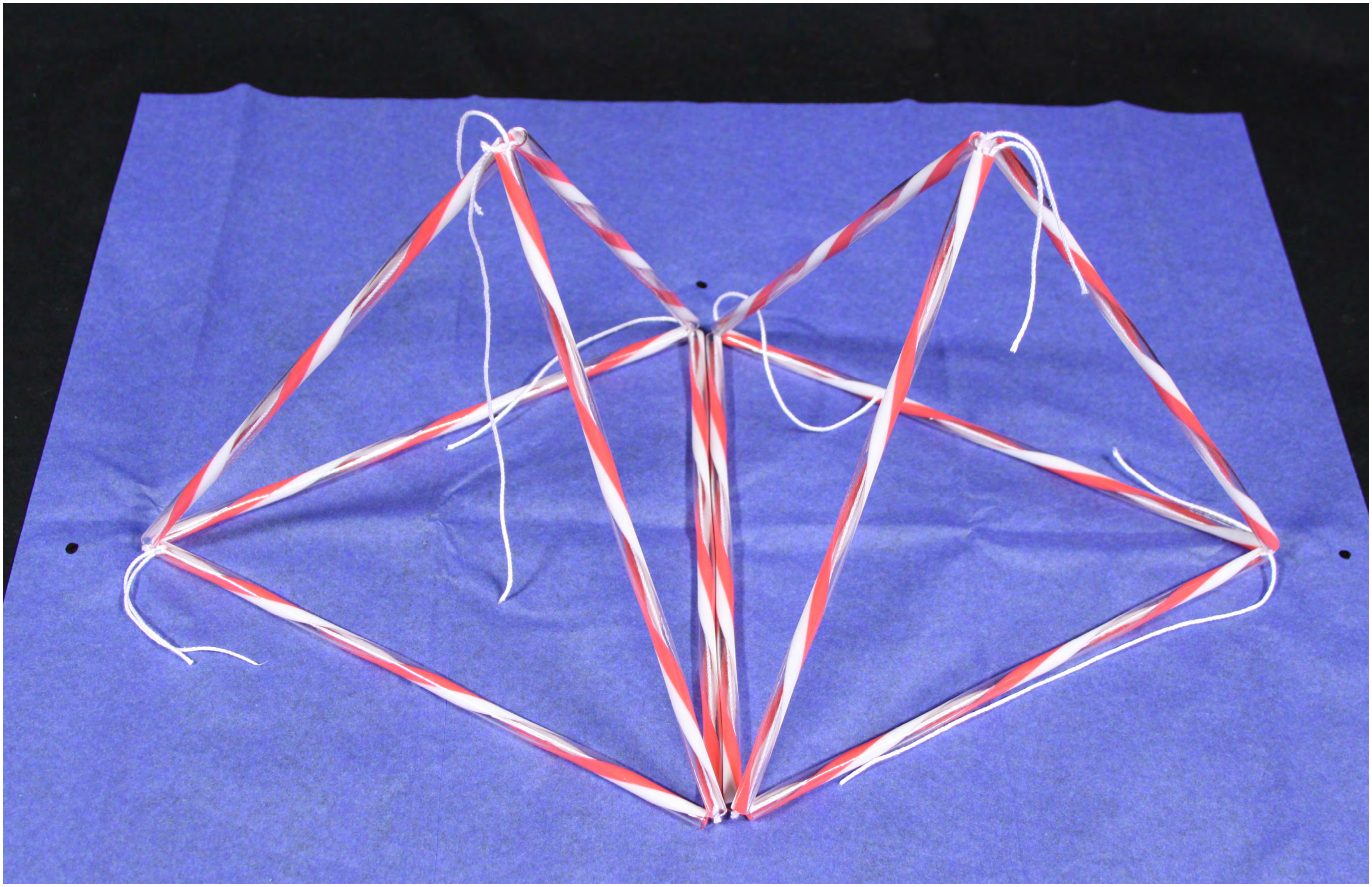


Fig. 8 Template construction

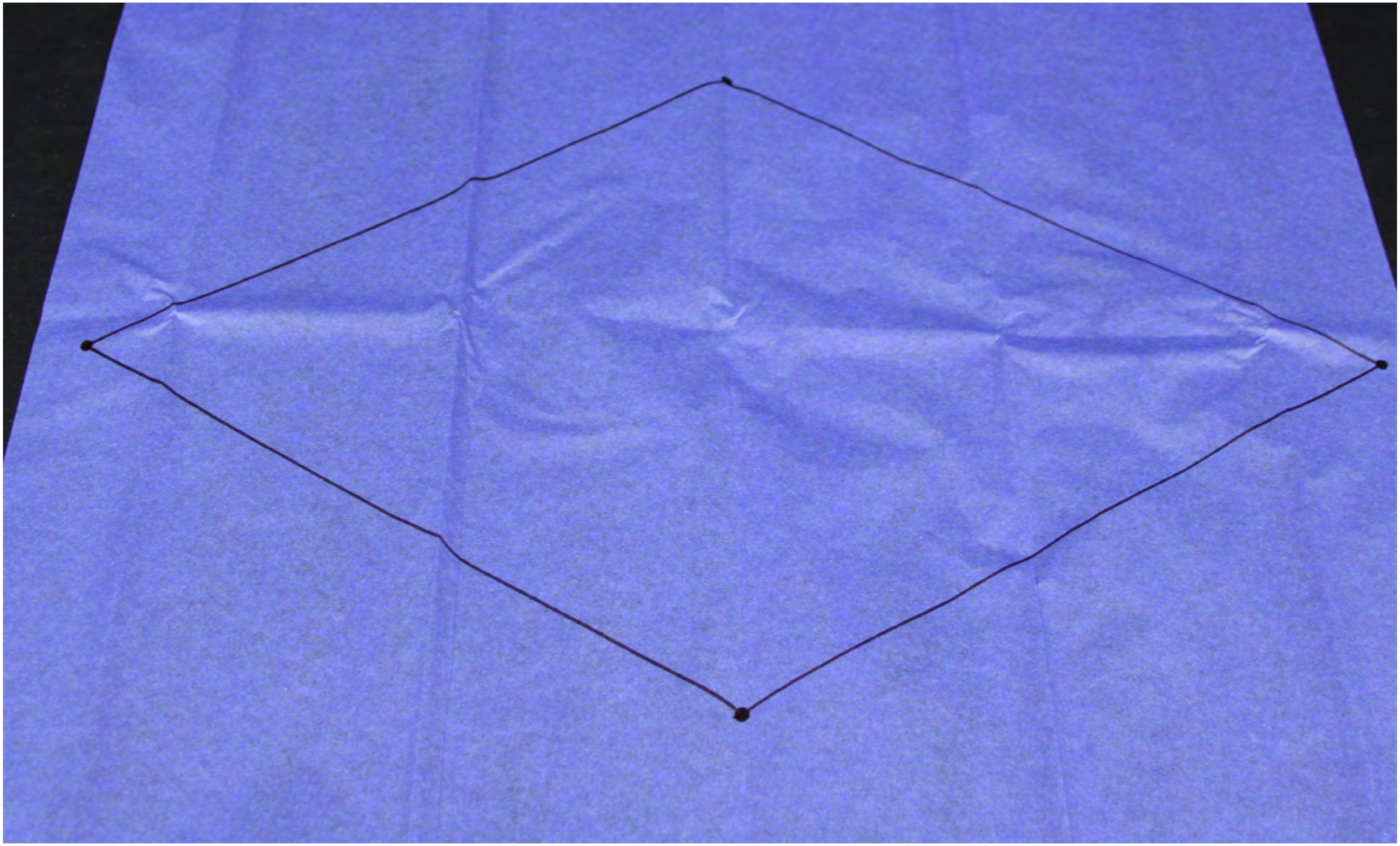


Fig. 9 Obtuse angle marking for template construction

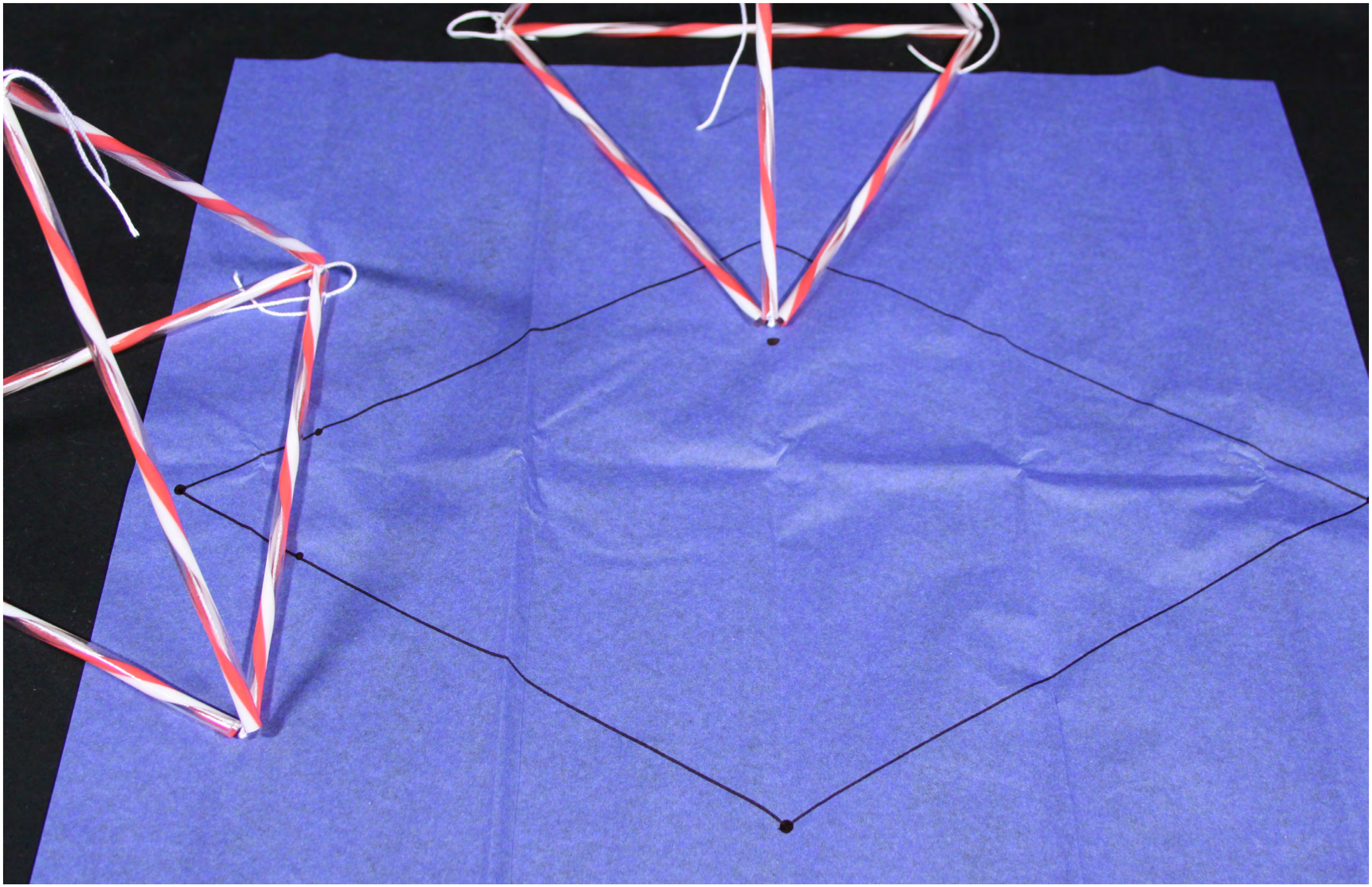


Fig. 10 Acute angle marking for template construction

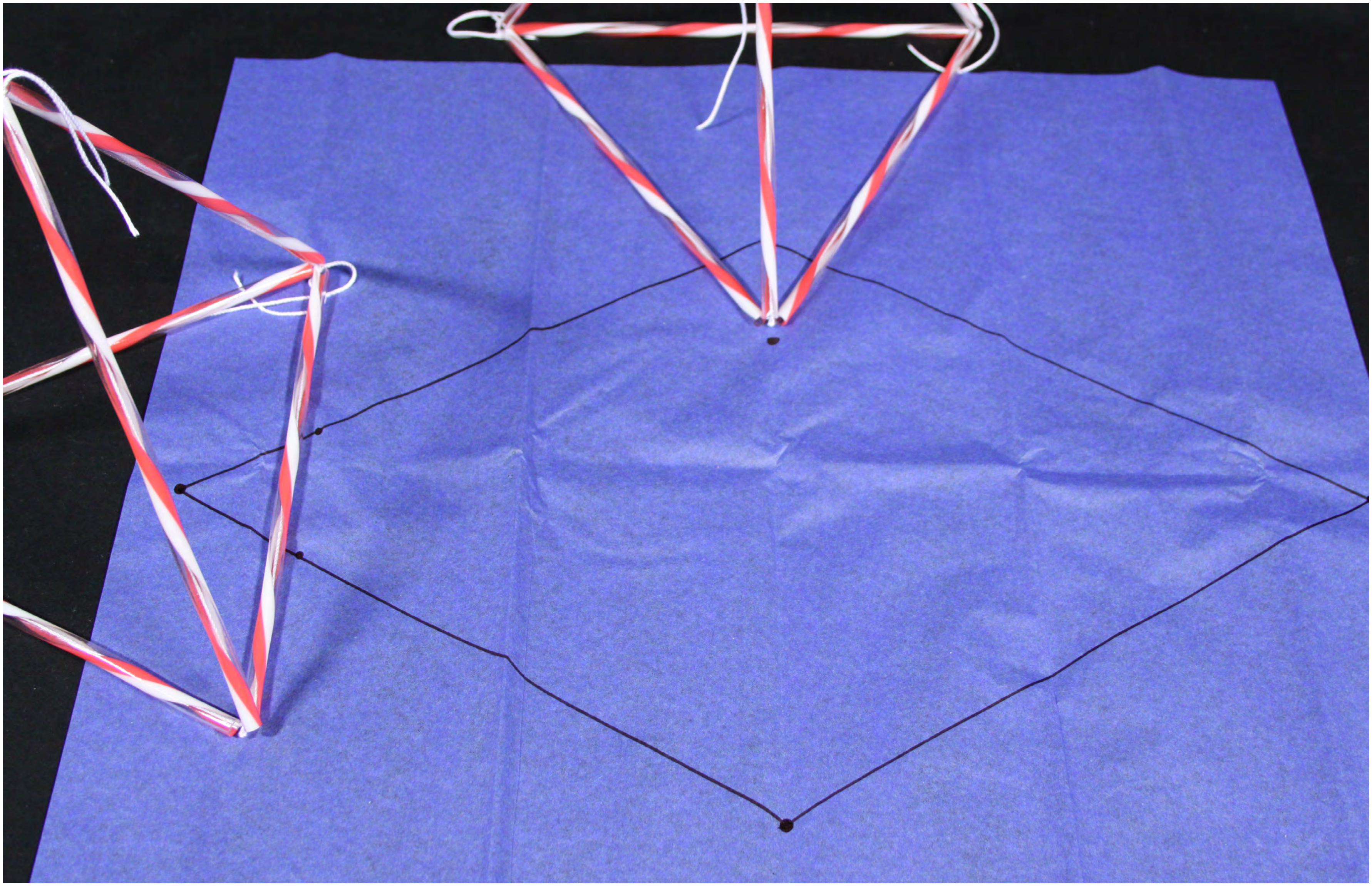


Fig. 11 Tissue paper template

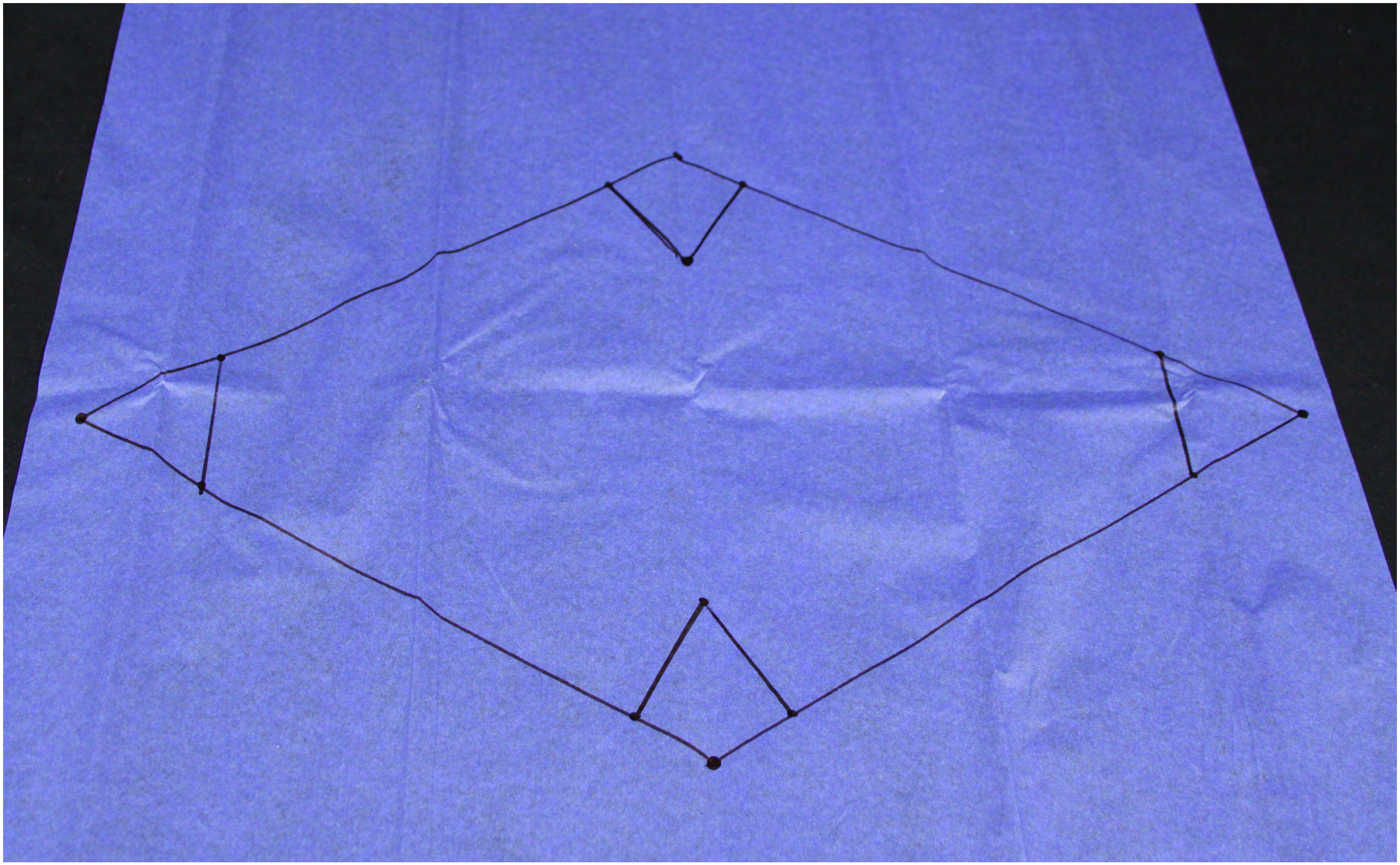


Fig. 12 Completed tissure paper template

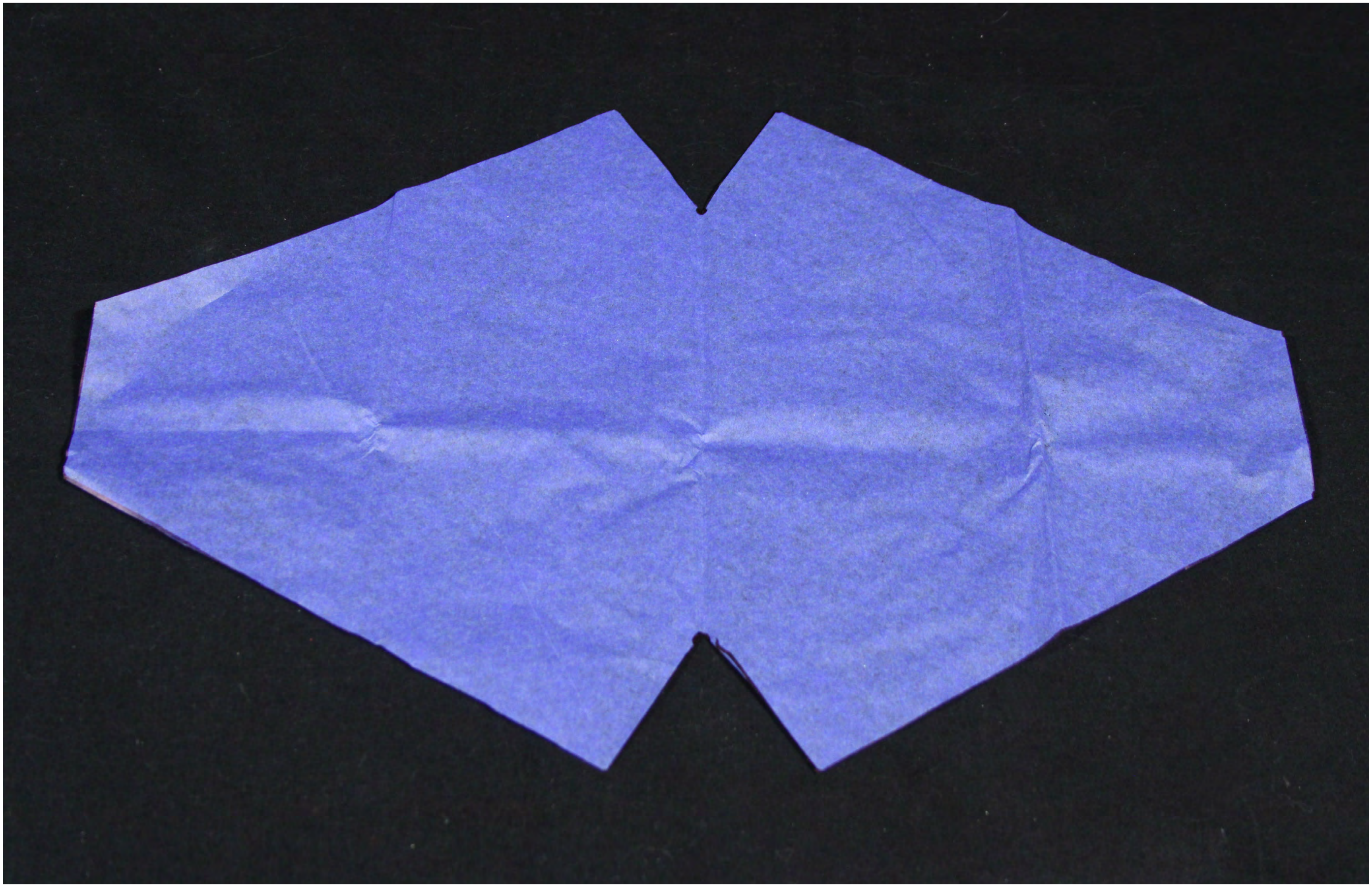


Fig. 13 Placement of tetrahedron on tissue paper template

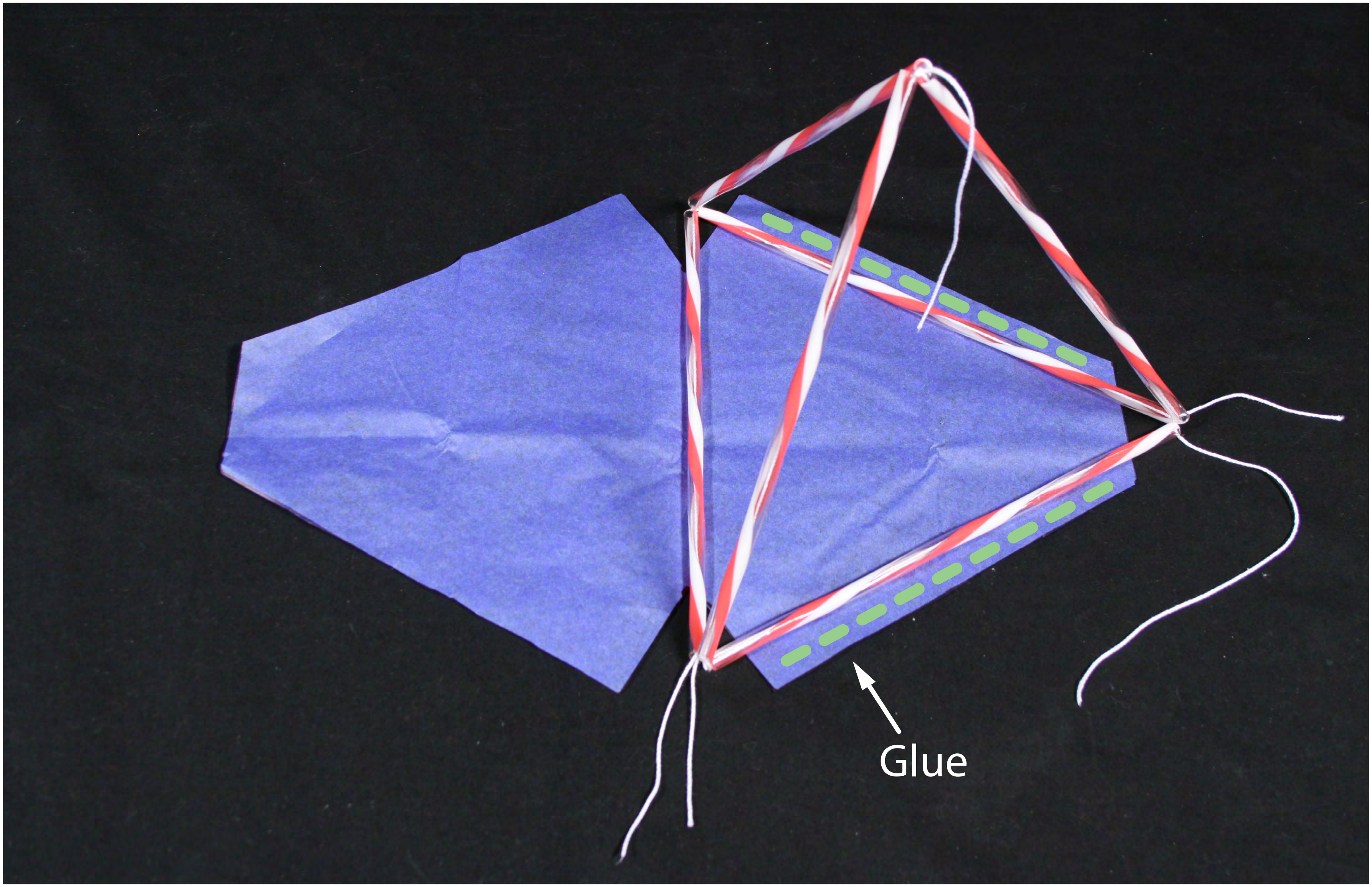


Fig. 14 Covered tetrahedron

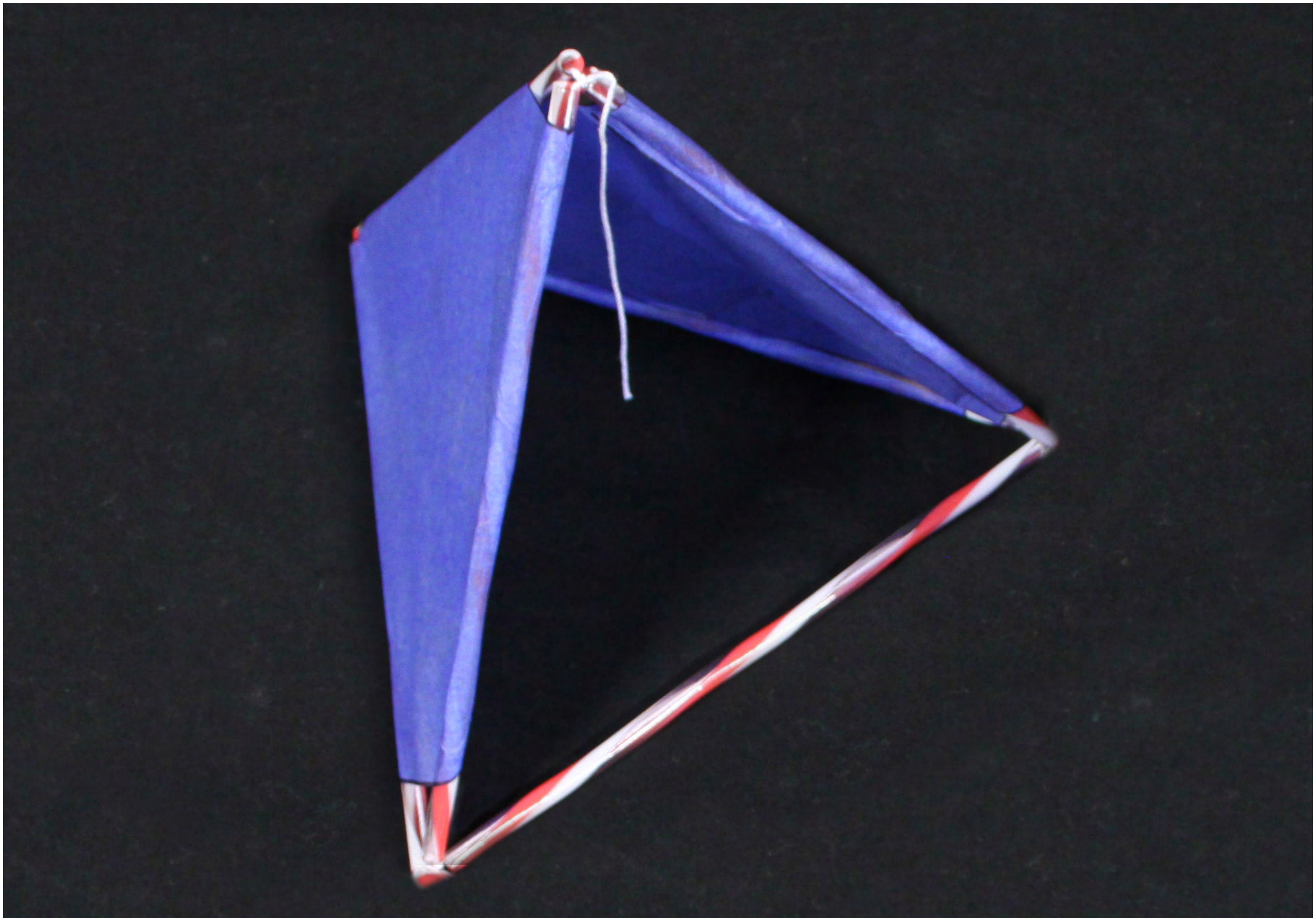


Fig. 15 Three tetrahedrons in the form of one large triangle

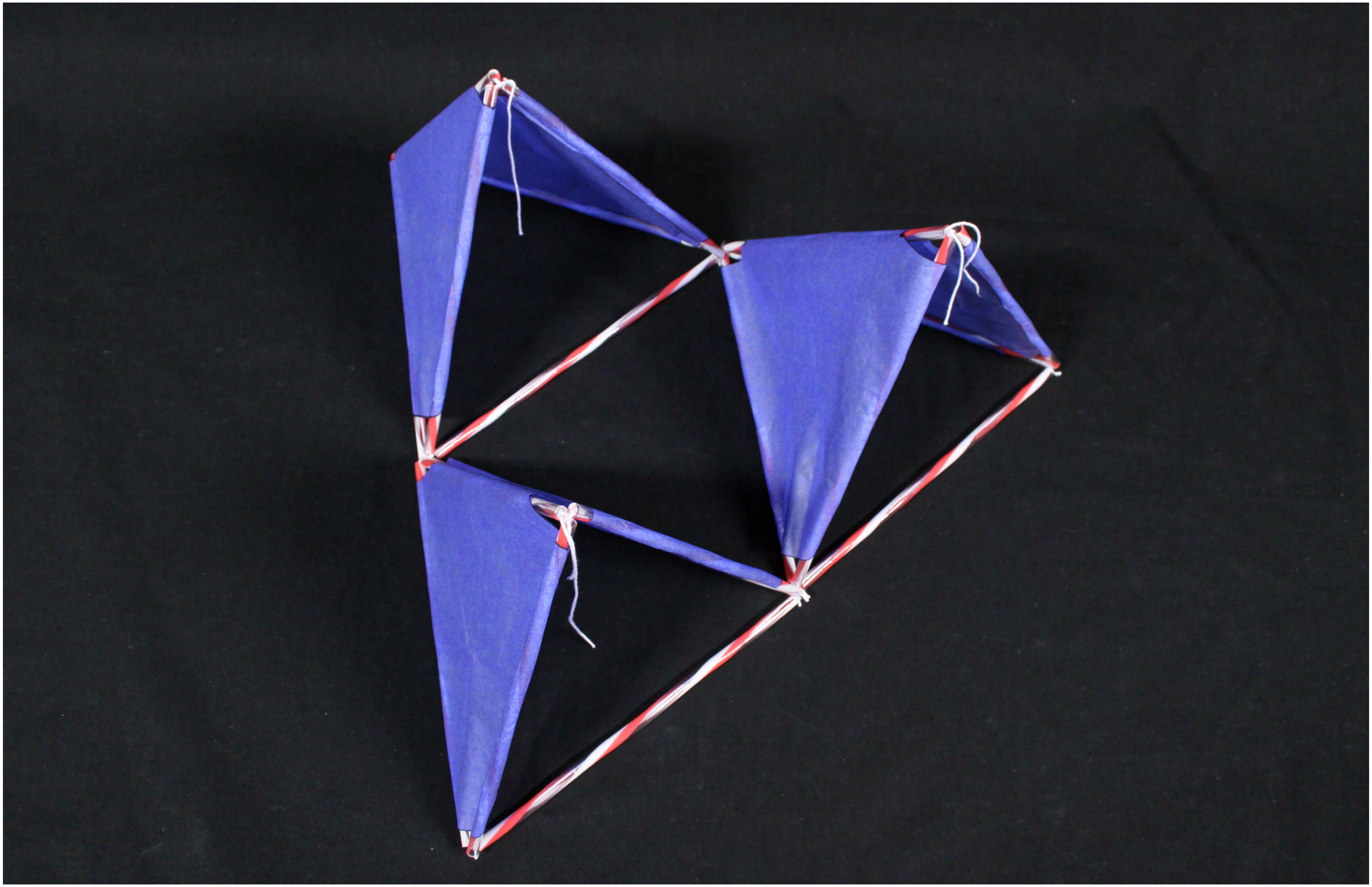
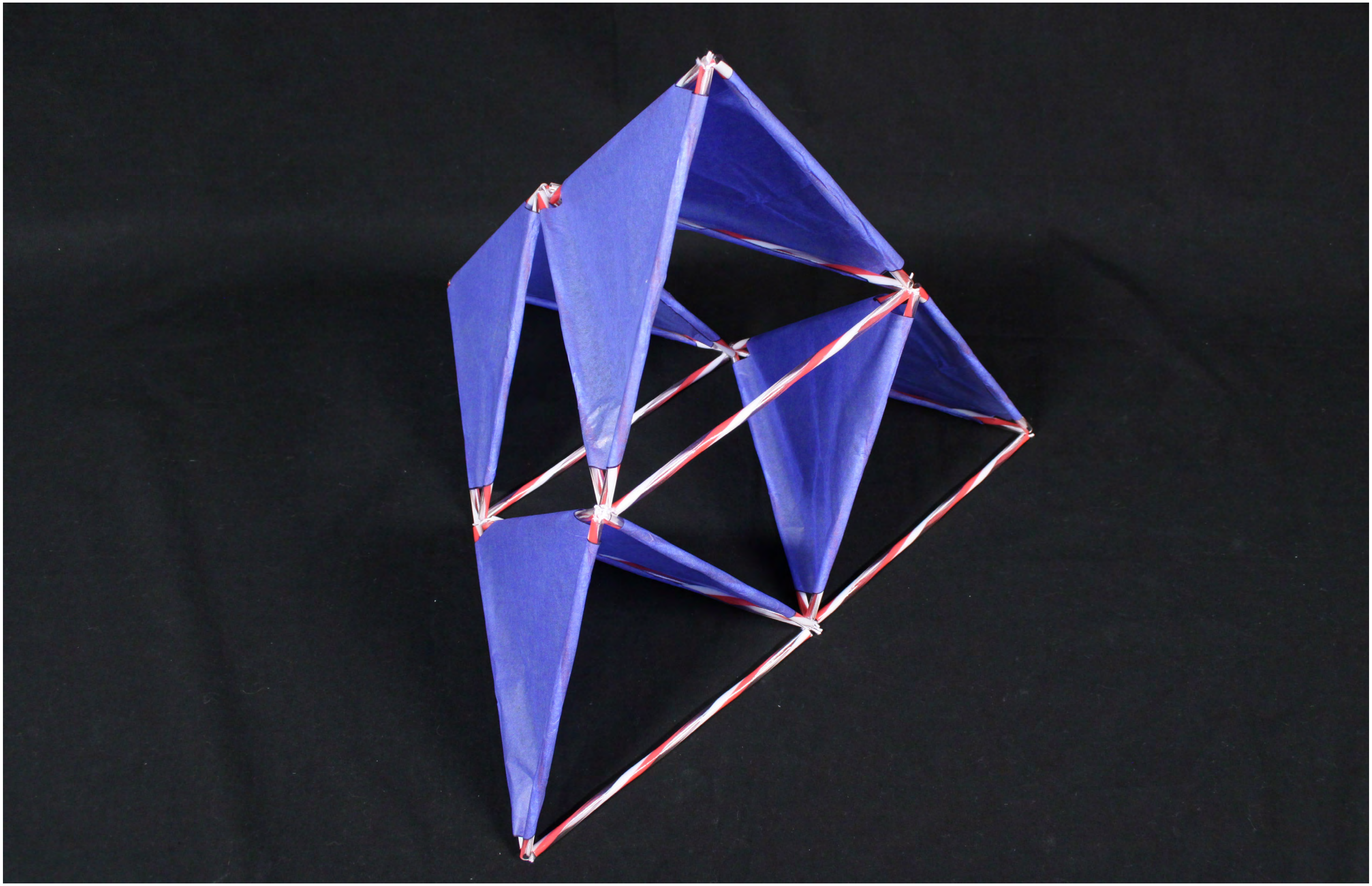


Fig. 16 4 Tetrahedrons



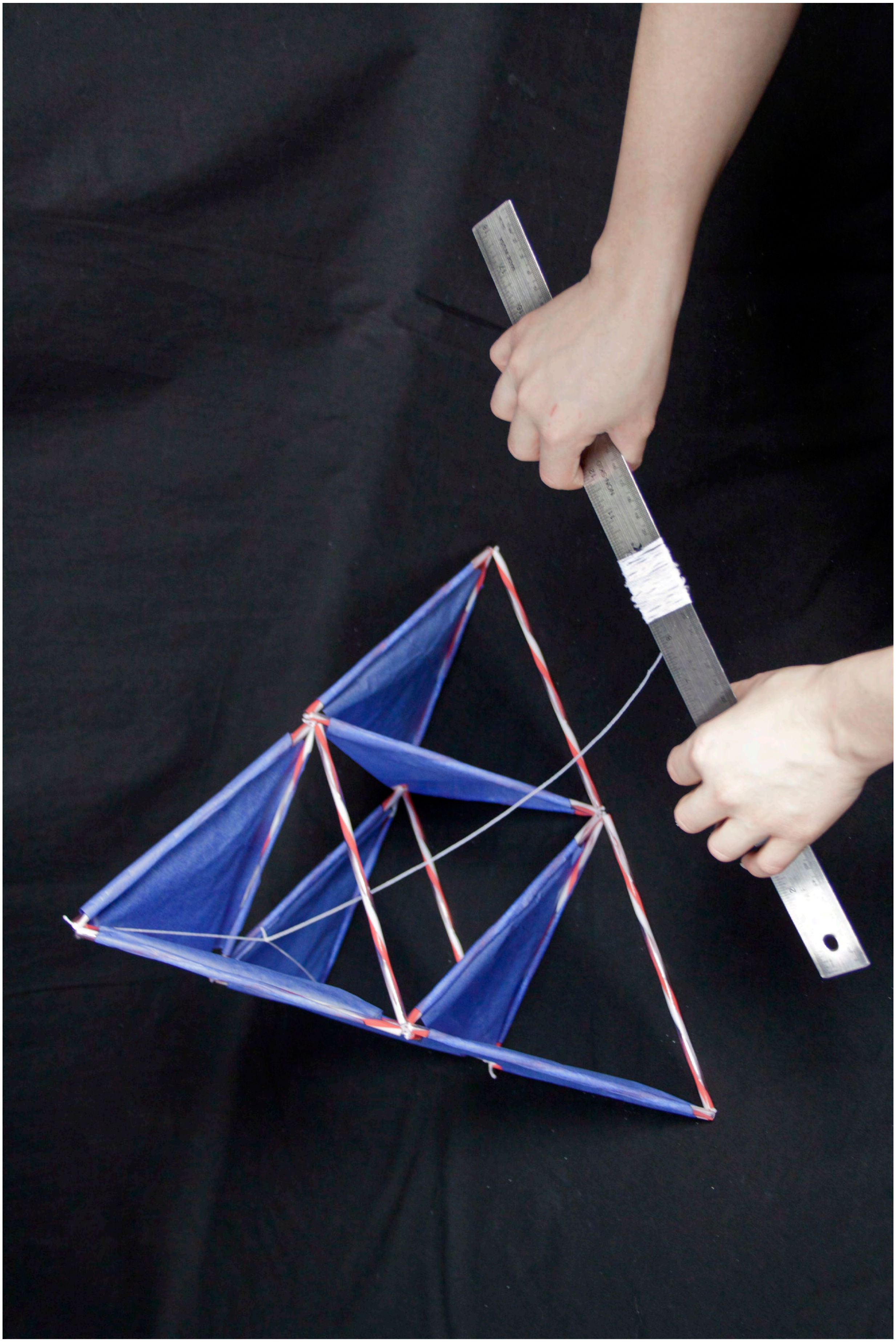


Fig. 17 Completed kite with bridle

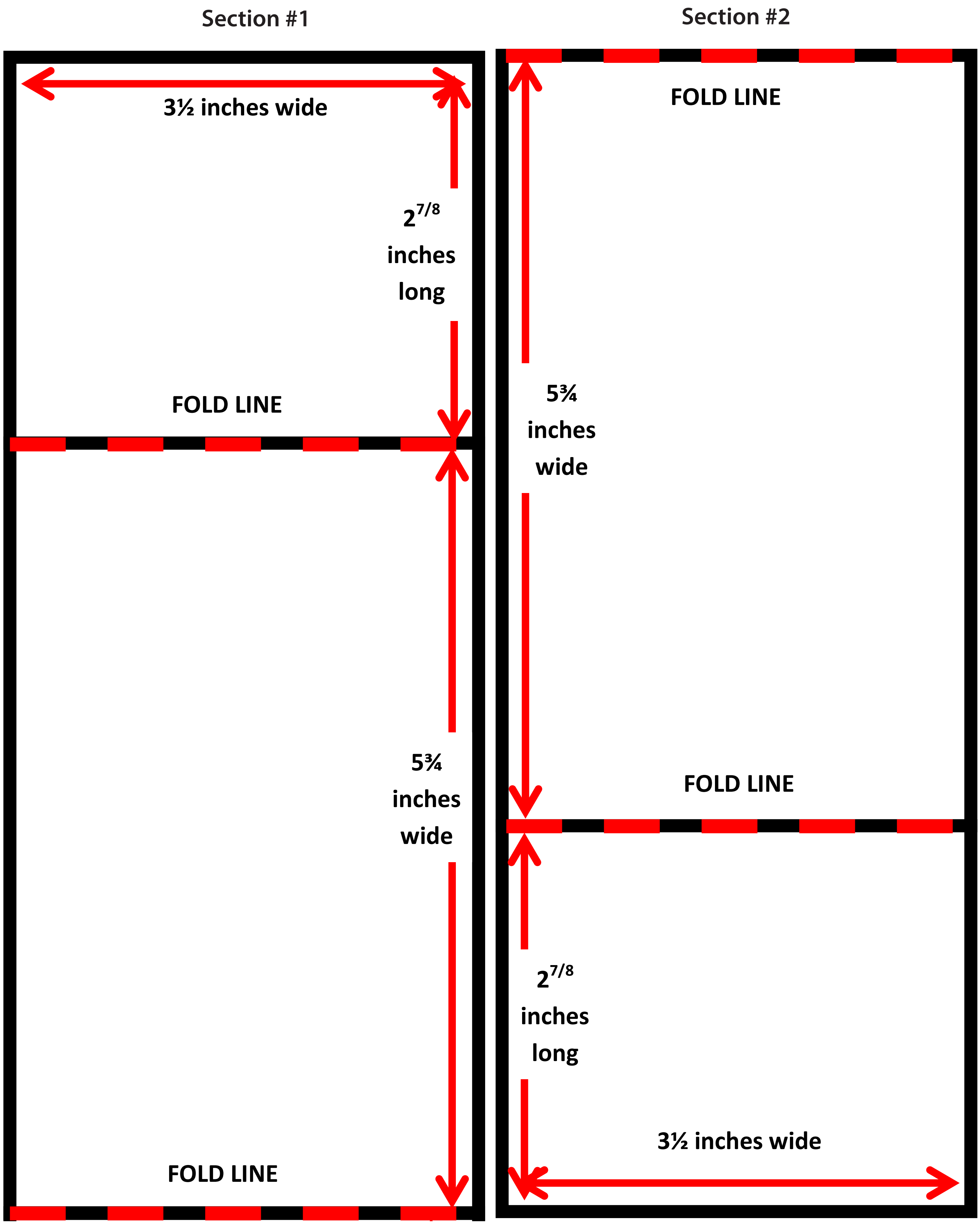


Fig. 18 Box Kite Template

Section #3

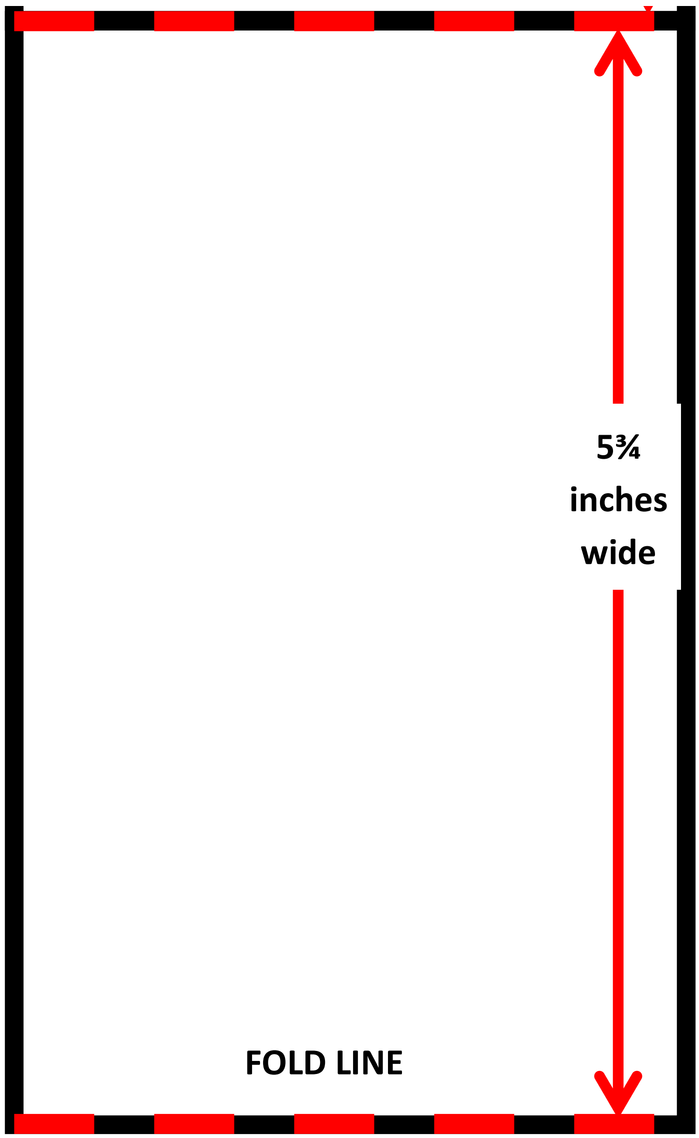


Fig. 18 Box Kite Template

Student Worksheets

Worksheet 1 Shape, Define and Design

Directions: Read the vocabulary word and definition. Next, rewrite the definition in your own words in the space provided below. A space is provided for you to draw your representation of this geometric term.

Apex:

The tip or point of an object.

Rewrite this definition in your own words.

Draw a representation of this shape or geometric term in the space provided below.

Directions: Read the vocabulary word and definition. Next, rewrite the definition in your own words in the space provided below. A space is provided for you to draw your representation of this geometric term.

Equilateral:
All sides of an object are equal.

Rewrite this definition in your own words.

Draw a representation of this shape or geometric term in the space provided below.

Worksheet 1 (cont.) Shape, Define and Design

Directions: Read the vocabulary word and definition. Next, rewrite the definition in your own words in the space provided below. A space is provided for you to draw your representation of this geometric term.

Equilateral Triangle:
A triangle that has three equal angles.

Rewrite this definition in your own words.

Draw a representation of this shape or geometric term in the space provided below.

Directions: Read the vocabulary word and definition. Next, rewrite the definition in your own words in the space provided below. A space is provided for you to draw your representation of this geometric term.

Pyramid:

A solid geometric shape that has a polygonal base and triangular sides that meet in a singular point.

Rewrite this definition in your own words.

Draw a representation of this shape or geometric term in the space provided below.

Worksheet 1 (cont.) Shape, Define and Design

Directions: Read the vocabulary word and definition. Next, rewrite the definition in your own words in the space provided below. A space is provided for you to draw your representation of this geometric term.

Triangle:
A closed plane figure or geometric shape that has three sides and three angles.

Rewrite this definition in your own words.

Draw a representation of this shape or geometric term in the space provided below.

Worksheet 1 (cont.) Shape, Define and Design

Directions: Read the vocabulary word and definition. Next, rewrite the definition in your own words in the space provided below. A space is provided for you to draw your representation of this geometric term.

Tetrahedron:
A solid triangular pyramid or a geometric shape comprised of four plane faces.

Rewrite this definition in your own words.

Draw a representation of this shape or geometric term in the space provided below.

Worksheet 1 (cont.)

Shape, Define and Design

Directions: Read the vocabulary word and definition. Next, rewrite the definition in your own words in the space provided below. A space is provided for you to draw your representation of this geometric term.

Vertex:
A point in a geometrical solid that is common to three or more sides.

Rewrite this definition in your own words.

Draw a representation of this shape or geometric term in the space provided below.

Use the space below to sketch a design for your straw pyramid.

Worksheet 2

Beaufort Wind Scale

Use the information below to fill in the Beaufort Wind Scale. Within your group, deduce the order and description of the wind scale. Once you have completed the scale, cross off your selections and then check your team's answers using the answer sheet.

Wind / Knots (Wind speed that is equal to one nautical mile per hour)	**World Meteorological Organization Classification (WMOC)**
7 - 10	Strong Gale
11 - 16	Storm
Less Than 1	Violent Storm
1 - 3	Light Breeze
4 - 6	Gentle Breeze
17 - 21	Fresh Breeze
22 - 27	Strong Breeze
48 - 55	Calm
56 - 63	Light Air
64+	Near Gale
28 - 33	Gale

Beaufort Wind Scale

Appearance of Wind Effects on Water	Appearance of Wind Effects on Land
Exceptionally high (30-45 ft) waves, foam patches cover sea, visibility more reduced	Small trees in leaf begin to sway
Sea surface smooth and mirror-like	Larger tree branches moving, whistling in wires
Large wavelets, crests begin to break, scattered whitecaps	Wind felt on face, leaves rustle, vanes begin to move
Small waves 1-4 ft. becoming longer, numerous whitecaps	Leaves and small twigs constantly moving, light flags extended
Scaly ripples, no foam crests	Calm, smoke rises vertically
Small wavelets, crests glassy, no breaking	Smoke drift indicates wind direction, still wind vanes
Moderate waves 4-8 ft taking longer form, many whitecaps, some spray	Dust, leaves, and loose paper lifted, small tree branches move
Larger waves 8-13 ft, whitecaps common, more spray	Slight structural damage occurs, slate blows off roofs
Sea heaps up, waves 13-20 ft, white foam streaks off breakers	Seldom experienced on land, trees broken or uprooted, "considerable structural damage"
Air filled with foam, waves over 45 ft, sea completely white with driving spray, visibility greatly reduced	Whole trees moving, resistance felt walking against wind
Moderately high (13-20 ft) waves of greater length, edges of crests begin to break into spindrift, foam blown in streaks	Twigs breaking off trees, generally impedes progress
High waves (20 ft), sea begins to roll, dense streaks of foam, spray may reduce visibility	
Very high waves (20-30 ft) with overhanging crests, sea white with densely blown foam, heavy rolling, lowered visibility	
Moderately high (18-25 ft) waves of greater length, edges of crests begin to break into spindrift, foam blown in streaks	

Worksheet 2 (cont.)

Beaufort Wind Scale

Please complete the Beaufort Wind Scale. To provide you with examples, several forces are completed for you:

Force	Wind (Knots)	WMO Classification	Appearance of Wind Effects on Land	Appearance of Wind Effects on Water
0				
1	1-3	Light Air	Smoke drift indicates wind direction, still wind vanes	Scaly ripples, no foam crests
2				
3				
4	11-16	Moderate Breeze	Dust, leaves, and loose paper lifted, small tree branches move	Small waves 1-4 feet, becoming longer, numerous whitecaps
5				
6				
7				
8				
9	41-47	Strong Gale	Slight structural damage occurs, slate blows off roofs	High waves (23 feet to 32 feet), sea begins to roll, dense streaks of foam, spray may reduce visibility
10				
11			NO RANKING FOR LAND - PLEASE SKIP	
12	64+	Hurricane	NO RANKING FOR LAND - PLEASE SKIP	Air filled with foam, waves over 45 feet, sea completely white with driving spray, visibility greatly reduced

Worksheet 2

Beaufort Wind Scale (Teacher Version)

Force	Wind (Knots)	WMO Classification	Appearance of Wind Effects on Land	Appearance of Wind Effects on Water
0	*Less than 1*	*Calm*	*Calm, smoke rises vertically*	*Sea surface smooth and mirror-like*
1	**1-3**	**Light Air**	**Smoke drift indicates wind direction, still wind vanes**	**Scaly ripples, no foam crests**
2	*4-6*	*Light Breeze*	*Wind felt on face, leaves rustle, vanes begin to move*	*Small wavelets, crests glassy, no breaking*
3	*7-10*	*Gentle Breeze*	*Leaves and small twigs constantly moving, light flags extended*	*Large wavelets, crests begin to break, scattered whitecaps*
4	**11-16**	**Moderate Breeze**	**Dust, leaves, and loose paper lifted, small tree branches move**	**Small waves 1-4 ft. becoming longer, numerous whitecaps**
5	*17-21*	*Fresh Breeze*	*Small trees in leaf begin to sway*	*Moderate waves 4-8 ft taking longer form, many whitecaps, some spray*
6	*22-27*	*Strong Breeze*	*Larger tree branches moving, whistling in wires*	*Larger waves 8-13 ft, whitecaps common, more spray*
7	*28-33*	*Near Gale*	*Whole trees moving, resistance felt walking against wind*	*Sea heaps up, waves 13-20 ft, white foam streaks off breakers*
8	*34-40*	*Gale*	*Whole trees in motion, resistance felt walking against wind*	*Moderately high (13-20 ft) waves of greater length, edges of crests begin to break into spindrift, foam blown in streaks*
9	**41-47**	**Strong Gale**	**Slight structural damage occurs, slate blows off roofs**	**High waves (20 ft), sea begins to roll, dense streaks of foam, spray may reduce visibility**
10	*48-55*	*Storm*	*Seldom experienced on land, trees broken or uprooted, "considerable structural damage"*	*Very high waves (20-30 ft) with overhanging crests, sea white with densely blown foam, heavy rolling, lowered visibility*
11	*56-63*	*Violent Storm*	**NO RANKING FOR LAND - PLEASE SKIP**	*Exceptionally high (30-45 ft) waves, foam patches cover sea, visibility more reduced*
12	**64+**	**Hurricane**	**NO RANKING FOR LAND - PLEASE SKIP**	**Air filled with foam, waves over 45 ft, sea completely white with driving spray, visibility greatly reduced**

Worksheet 3

Triangles in Numbers

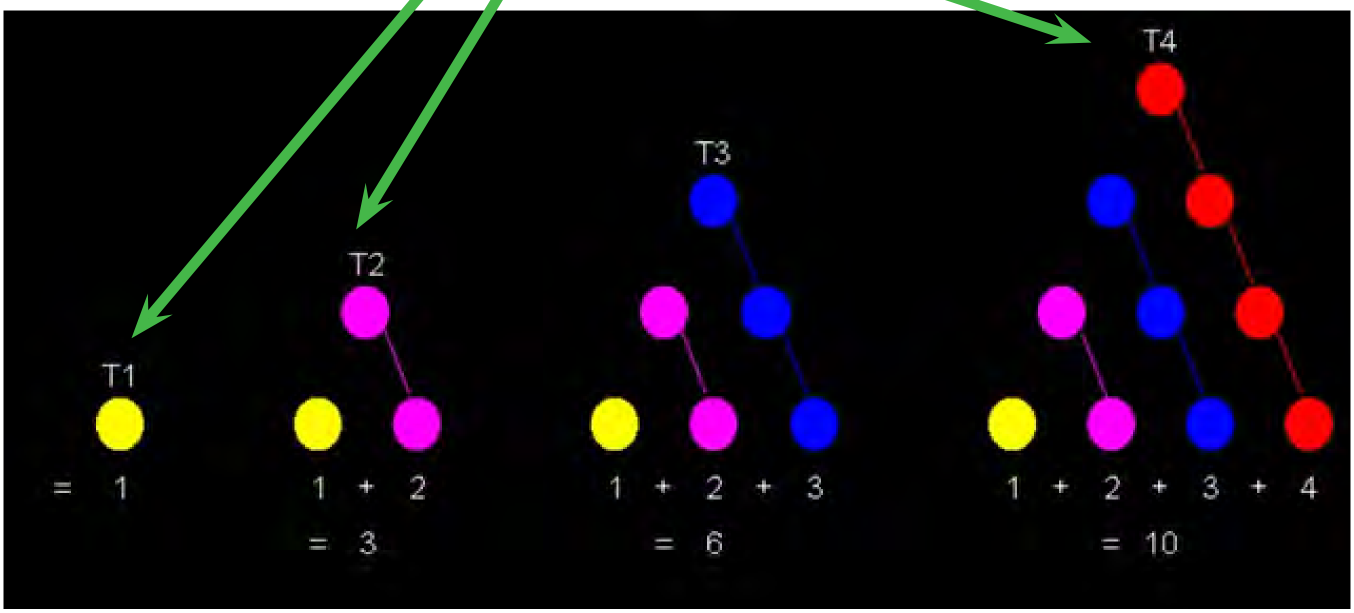
Below is a sample math problem of a triangular number. Note there are four different layers. One is represented with numbers and the other is represented through dots that form triangles. Please complete similar mathematical problems below to understand the different levels.

1

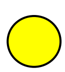
1+2=3

(1+2)+3=6

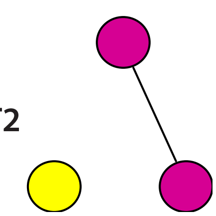
(1+2+3)+4=10



We are going to do the fifth level together. Then you will be asked to do the next five levels yourself.

If (1) = Level 1 or T1 

Then (1+2)=3 is Level 2 or T2



Worksheet 3 (cont.) Triangles in Numbers

It follows that by looking at the first four levels, the fifth level would look like this:

1

1+2=3

(1+2)+3=6

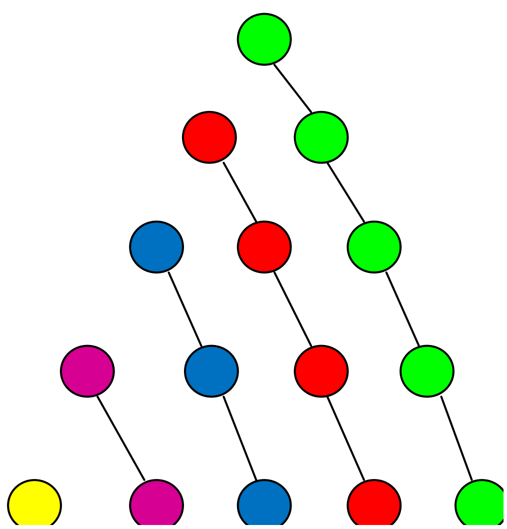
(1+2+3)+4=10

(1+2+3+4)+5=15

(1+2+3+4)+5=15

This would be considered the fifth level or layer.

If you were to represent this in a figure with dots in triangles, this is how it would look:



1 + 2 + 3 + 4 + 5 - = 15

You will be asked to show both of these representations in your mathematical problems. Colored pencils or markers may help in representing the different layers. If you have any questions do not hesitate to ask your instructor.

Worksheet 3 (cont.) Triangles in Numbers

Problem #1

Please write the mathematical representation using numbers to show six levels or layers.

Level 1_____

Level 2__________

Level 3_______________

Level 4____________________

Level 5_________________________

Level 6______________________________

Problem #2

Represent your answer in problem #1 in dots and triangles as we did together above. It is recommended that you use colored pencils or markers.

Problem #3

Please write the mathematical representation using numbers to show seven levels or layers.

Level 1_____

Level 2__________

Level 3_______________

Level 4____________________

Level 5_________________________

Level 6______________________________

Level 7___________________________________

Problem #4

Represent your answer in problem #3 in dots and triangles as we did together above. It is recommended that you use colored pencils or markers.

Problem #5

Please write the mathematical representation using numbers to show six levels or layers.

Level 1_____

Level 2__________

Level 3_______________

Level 4____________________

Level 5_________________________

Level 6______________________________

Level 7___________________________________

Level 8____

Problem #6

Represent your answer in problem #5 in dots and triangles as we did together above. It is recommended that you use colored pencils or markers.

Problem #7

Please write the mathematical representation using numbers to show seven levels or layers.

Level 1_____

Level 2__________

Level 3_______________

Level 4____________________

Level 5_________________________

Level 6______________________________

Level 7___________________________________

Level 8____

Level 9____

Problem #8

Represent your answer in problem #7 in dots and triangles as we did together above. It is recommended that you use colored pencils or markers.

Worksheet 3 (cont.) Triangles in Numbers

Problem #9

Please write the mathematical representation using numbers to show seven levels or layers.

Level 1_____

Level 2__________

Level 3_______________

Level 4____________________

Level 5_________________________

Level 6______________________________

Level 7___________________________________

Level 8____

Level 9____

Level 10____

Problem #10

Represent your answer in problem #9 in dots and triangles as we did together above. It is recommended that you use colored pencils or markers.

Worksheet 3

Triangles in Numbers (Teacher Version)

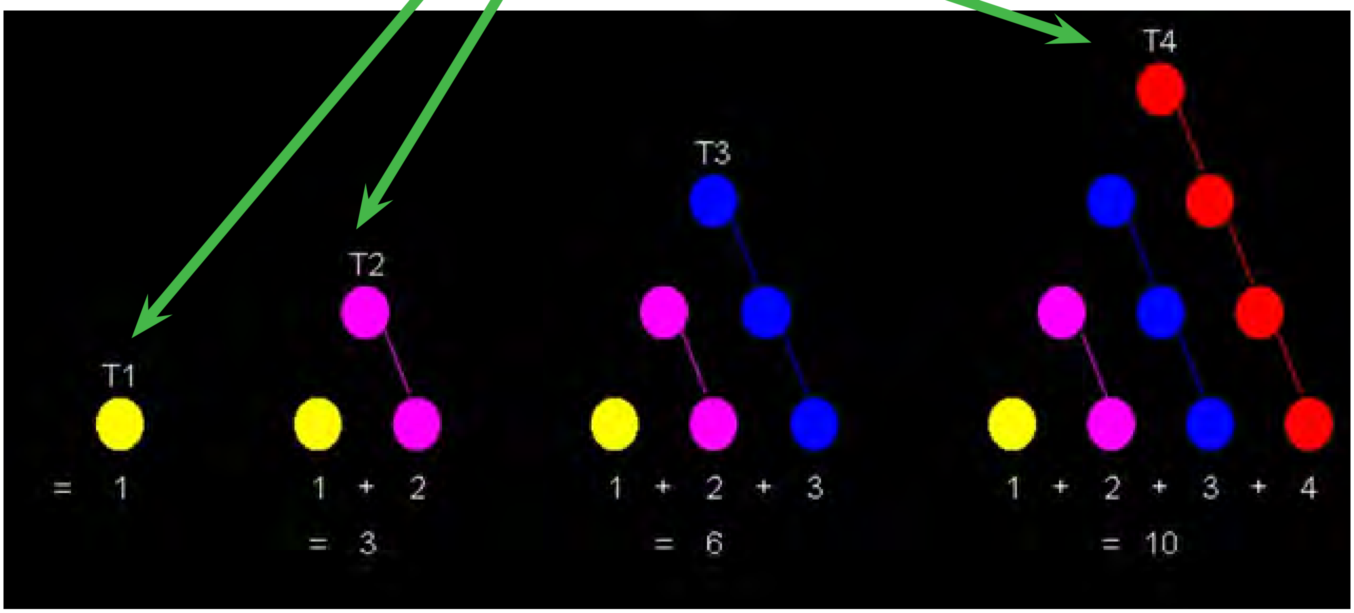
Below is a sample math problem of a triangular number. Note there are four different layers. One is represented with numbers and the other is represented through dots that form triangles. Please complete similar mathematical problems below to understand the different levels.

1

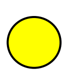
1+2=3

(1+2)+3=6

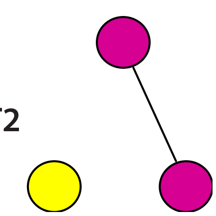
(1+2+3)+4=10



We are going to do the fifth level together. Then you will be asked to do the next five levels yourself.

If (1) = Level 1 or T1 

Then (1+2)=3 is Level 2 or T2



Worksheet 3 (cont.) Triangles in Numbers (Teacher Version)

It follows that by looking at the first four levels, the fifth level would look like this:

1

1+2=3

(1+2)+3=6

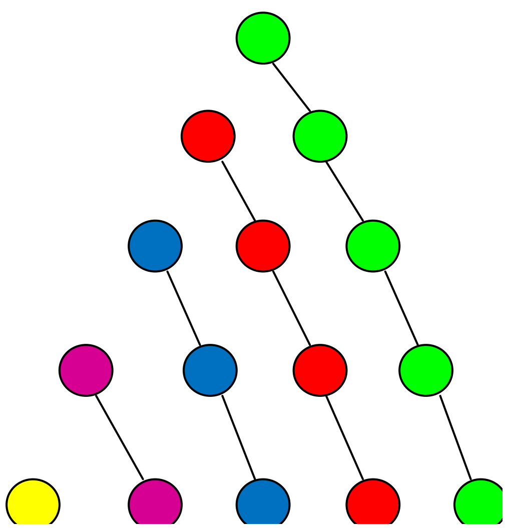
(1+2+3)+4=10

(1+2+3+4)+5=15

(1+2+3+4)+5=15

This would be considered the fifth level or layer.

If you were to represent this in a figure with dots in triangles, this is how it would look:



1 + 2 + 3 + 4 + 5 - = 15

You will be asked to show both of these representations in your mathematical problems. Colored pencils or markers may help in representing the different layers. If you have any questions do not hesitate to ask your instructor.

Problem #1

Please write the mathematical representation using numbers to show six levels or layers.

Level 1 1

Level 2 1+2=3

Level 3 (1+2)+3=6

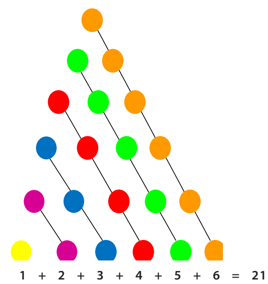
Level 4 (1+2+3)+4=10

Level 5 (1+2+3+4)+5=15

Level 6 (1+2+3+4+5)+6=21

Problem #2

Represent your answer in problem #1 in dots and triangles as we did together above. It is recommended that you use colored pencils or markers.



Problem #3

Please write the mathematical representation using numbers to show seven levels or layers.

Level 1 1

Level 2 1+2=3

Level 3 (1+2)+3=6

Level 4 (1+2+3)+4=10

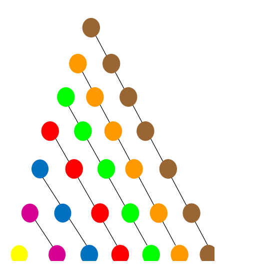
Level 5 (1+2+3+4)+5=15

Level 6 (1+2+3+4+5)+6=21

Level 7 (1+2+3+4+5+6)+7=28

Problem #4

Represent your answer in problem #3 in dots and triangles as we did together above. It is recommended that you use colored pencils or markers.



Worksheet 3 (cont.) Triangles in Numbers (Teacher Version)

Problem #5

Please write the mathematical representation using numbers to show six levels or layers.

Level 1 1

Level 2 1+2=3

Level 3 (1+2)+3=6

Level 4 (1+2+3)+4=10

Level 5 (1+2+3+4)+5=15

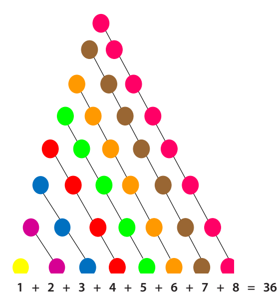
Level 6 (1+2+3+4+5)+6=21

Level 7 (1+2+3+4+5+6)+7=28

Level 8 (1+2+3+4+5+6+7)+8=36

Problem #6

Represent your answer in problem #5 in dots and triangles as we did together above. It is recommended that you use colored pencils or markers.



Problem #7

Please write the mathematical representation using numbers to show seven levels or layers.

Level 1 1

Level 2 1+2=3

Level 3 (1+2)+3=6

Level 4 (1+2+3)+4=10

Level 5 (1+2+3+4)+5=15

Level 6 (1+2+3+4+5)+6=21

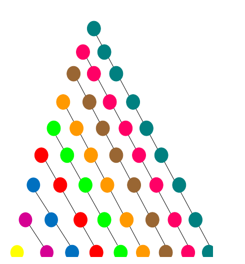
Level 7 (1+2+3+4+5+6)+7=28

Level 8 (1+2+3+4+5+6+7)+8=36

Level 9 (1+2+3+4+5+6+7+8)+9=45

Problem #8

Represent your answer in problem #7 in dots and triangles as we did together above. It is recommended that you use colored pencils or markers.



Problem #9

Please write the mathematical representation using numbers to show seven levels or layers.

Level 1 1

Level 2 1+2=3

Level 3 (1+2)+3=6

Level 4 (1+2+3)+4=10

Level 5 (1+2+3+4)+5=15

Level 6 (1+2+3+4+5)+6=21

Level 7 (1+2+3+4+5+6)+7=28

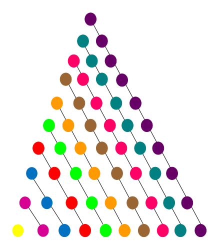
Level 8 (1+2+3+4+5+6+7)+8=36

Level 9 (1+2+3+4+5+6+7+8)+9=45

Level 10 (1+2+3+4+5+6+7+8+9)+10=55

Problem #10

Represent your answer in problem #9 in dots and triangles as we did together above. It is recommended that you use colored pencils or markers.



1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10 = 55

Worksheet 4 Tetrahedral Kite

Section One - Create a Tetrahedron Cell

1. You will need the following supplies for this step: string, 6 straws (no longer than 8 inches long), scissors, and a flat surface.
2. First, cut a length of yarn/string four (4) feet long. (If the cut string has not already been provided.)
3. Second, take 6 straws and place them flat on the surface.
4. Use your piece of string to string 3 straws together. One end of the conjoined 3 straws should have two strings extended, 1) approximately 20 inches long, and 2) approximately 4 inches long.
5. Tie these two ends of the string tightly together to make sure that there is no room for the triangle to "wiggle."
6. The three straws should form a tight triangle.
7. There should be one a short and long piece of string now hanging off of the ends of two conjoined straws.
8. See fig. 2 as an example of a tight, three-straw triangle.

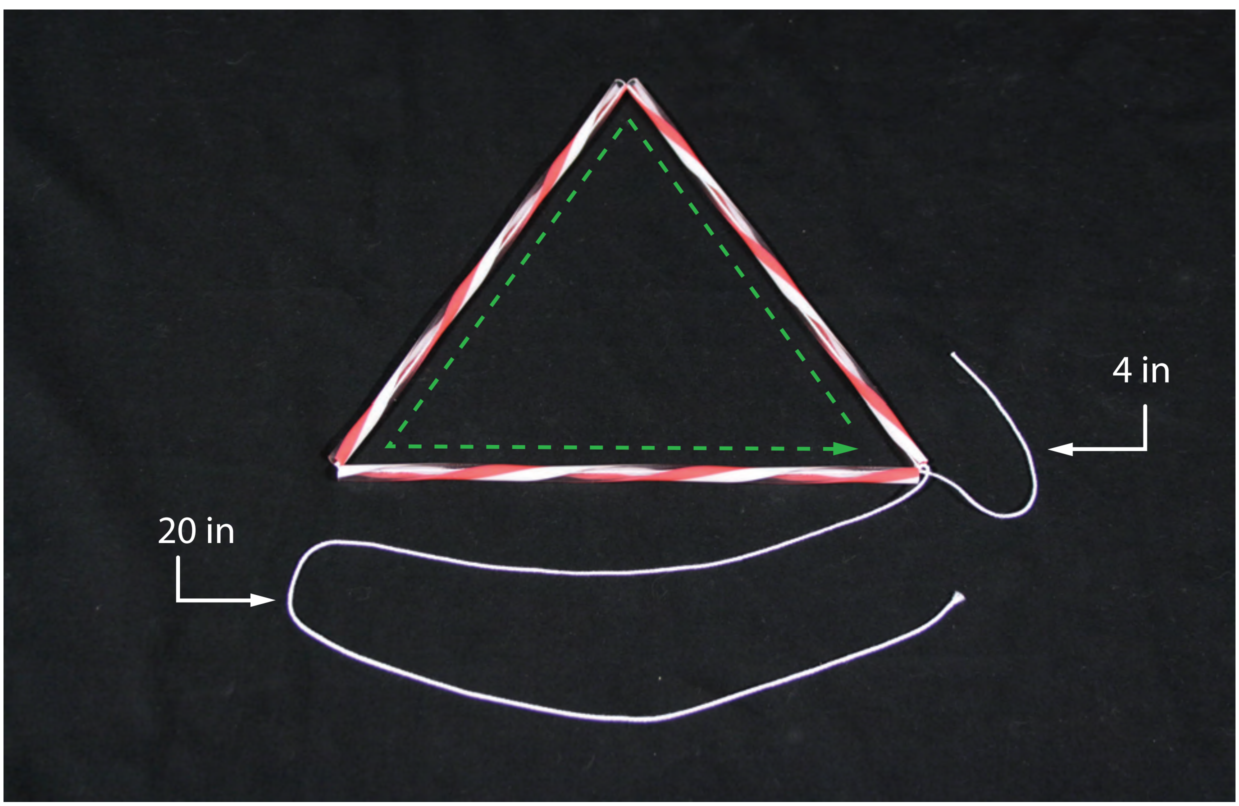


Fig. 2 Triangle

Worksheet 4

Tetrahedral Kite

Section One Questions

You have now completed the first part of constructing a tetrahedron. You have made a triangle connecting three straws. Record the following facts about the triangle:

1. Length of a side in inches = ________________________________

2. The measurement of each angle on the triangle = ________________________________

   Hint: 3 angles added together = 180°

3. Height of the triangle = ________________________________

4. Area of the triangle = ________________________________

5. All sides are equal ***or*** are not equal. (Circle one.)

6. All angles are equal ***or*** are not equal. (Circle one.)

7. This type of triangle is called an ________________________________ triangle.

Worksheet 4 (cont.) Tetrahedral Kite

Section Two - Create a Rhombus

1. **The three straws should form a tight triangle.**

2. **Cut another 4 inch piece of string and tie one end to any empty corner of the triangle.**

3. **Take one end of the 4-inch string, and tie that end to any empty corner of the triangle.**

4. **Now, add 2 more straws onto the longest piece of string.**

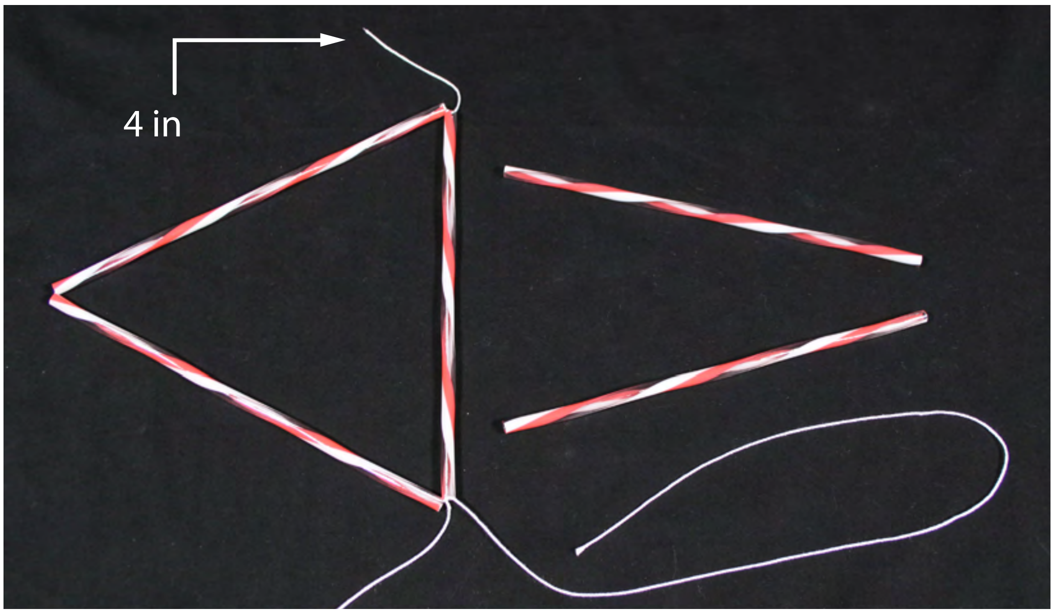


Fig. 3 Rhombus construction

5. **Next, take the string that holds the two additional straws and tie it to the end of the 4-inch string closest to the straw to make a another tight triangle. See picture below:**

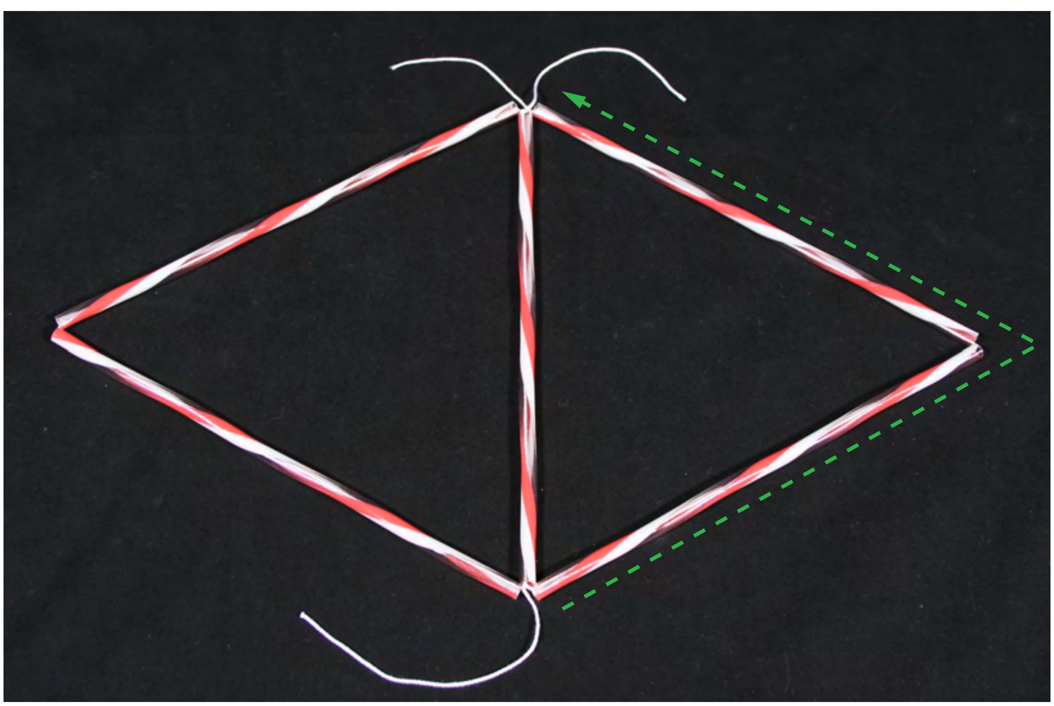


Fig. 4 Completed Rhombus

Worksheet 4 (cont.) Tetrahedral Kite

Section Two Questions

You have now completed the second part of constructing a tetrahedron and have made a rhombus. Record the following facts about the rhombus:

1. Length of a side in inches = ______________________________

2. The measurement of each angle in the rhombus = ___________ ___________ ___________ ________

   Hint: 4 angles added together = 360°

3. Height of the rhombus = ______________________________

4. Area of the rhombus = ______________________________

5. All sides are equal ***or*** are not equal. Circle one.)

6. All angles are equal ***or*** are not equal. (Circle one).

Worksheet 4 (cont.) Tetrahedral Kite

Section Three - Create a Three Dimensional Tetrahedron

1. **Cut another 4-inch piece of string.**

2. **Take that 4-inch piece of string and tie one of its ends to one of the empty corners.**

3. **Next, cut a piece of string that is double the length of one straw (or side of a tetrahedron).**

4. **Tie one end of that double-length string to the remaining empty corner. See picture below:**

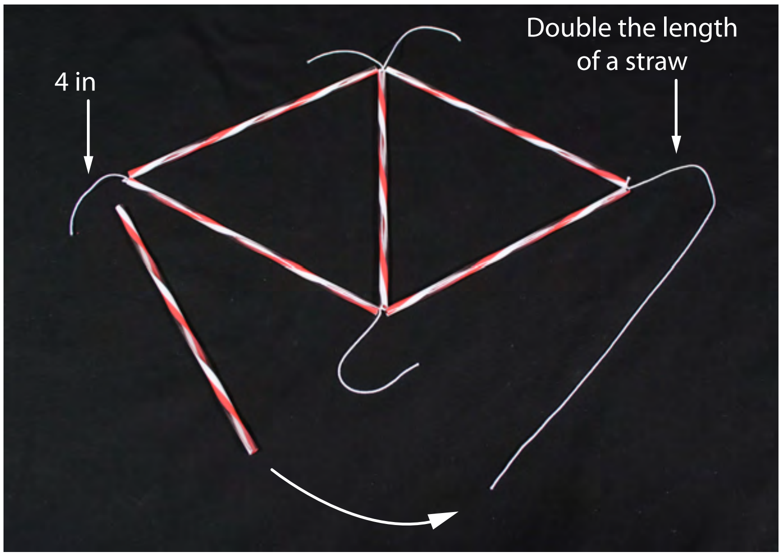


Fig. 5 Three dimensional tetrahedron construction

5. **Now, add the last straw onto the double-length string.**

6. **Tie together the two opposite ends (the end of the 4-inch string and the end of the double-length string closest to the straws) to form a tight 3-dimensional tetrahedron.**

7. **Follow all instructions in Steps 1, 2 and 3 to create a second tetrahedron.**

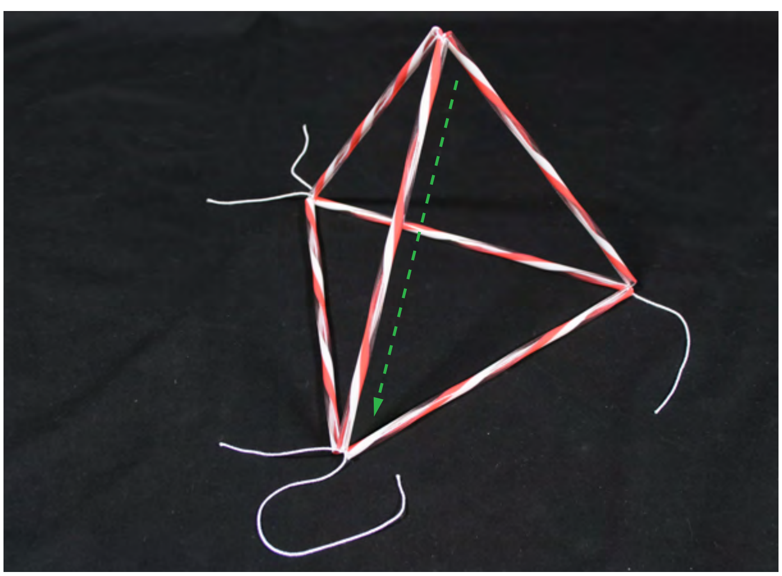


Fig. 6 Completed three dimensional tetrahedron

Tetrahedral Kite

Section Three Questions

You have now completed the third set of steps and have constructed a tetrahedron. Record the following facts about the tetrahedron:

1. How many triangular faces or surfaces does it have? ______________________________

2. What is the volume? ______________________________

   Hint: First you must find the area of the base.

   That formula is Area = ½ x Base x Height

   Hint: The formula for finding the volume is

   Volume = 1/3 x (area of the base) x Height

Worksheet 4 (cont.) Tetrahedral Kite

Section Four - Create a Tetrahedron Tissue Paper Cover

1. Remember to pay attention to the length of the straws as the template may be different and may need to be adjusted in size since straws come in a variety of lengths.
2. Choose a piece of colored tissue paper.
3. Fold the paper so that it will fill the template shown below in figure 10.
4. Place your tetrahedron on the tissue paper so that you are able to trace around the edges.
5. Now trace around the edges lightly with a pen or pencil.
6. Cut out the pattern that you just traced and open it.
7. See the picture below (fig. 7, 8, 9 & 10). Your tissue paper should look like this:

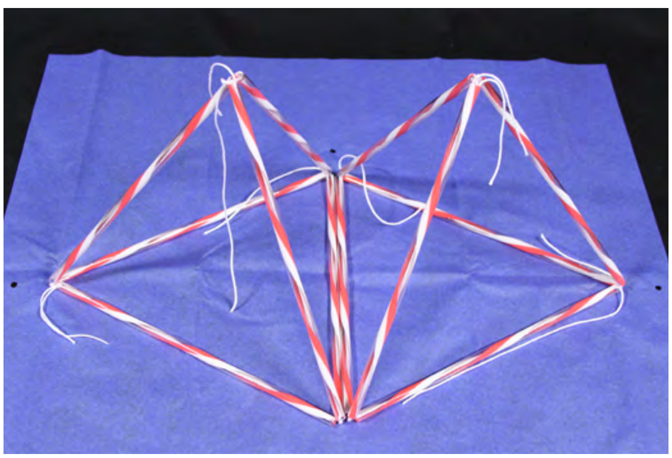


Fig. 7 One-inch marks to create template

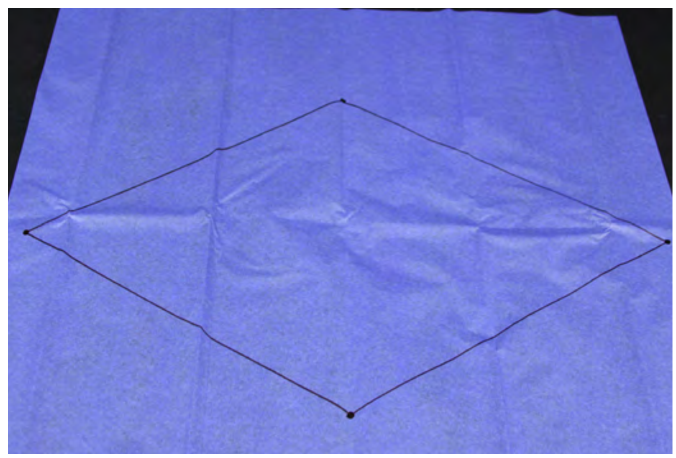


Fig. 8 Template construction

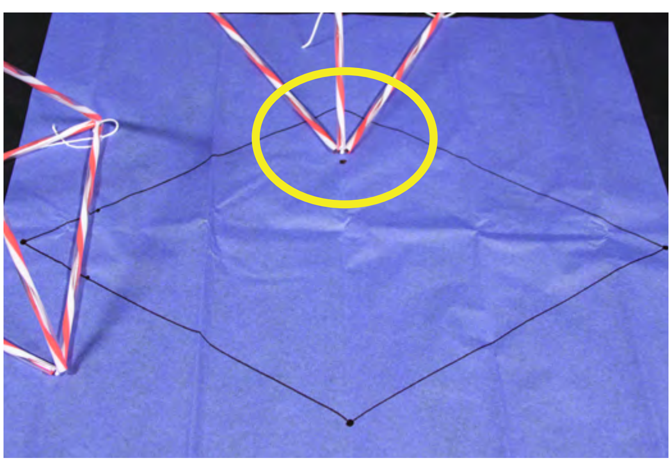


Fig. 9 Obtuse angle marking for template construction

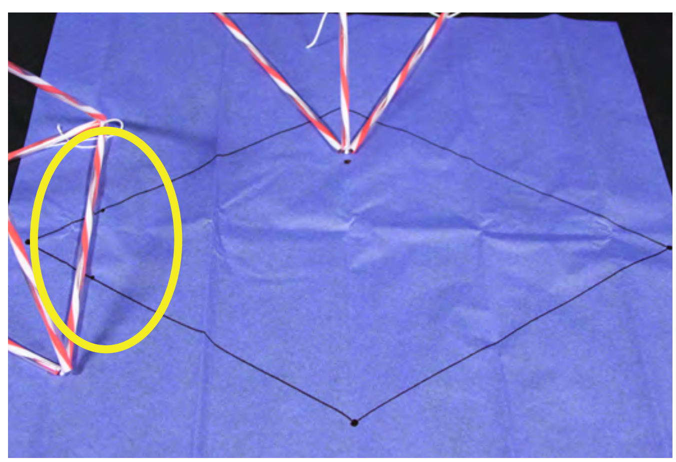


Fig. 10 Acute angle marking for template construction

Section Five - Cover the Tetrahedron

1. **Lay the tissue paper on your table.**
2. **Wrap the tissue paper around the two sides of the tetrahedron.**
3. **Now glue the tabs using a glue stick and fold them around the straws. (Spread the glue along the flaps and fold the flaps over the straws.) Make sure that it is a tight fit.**
4. **Rotate the tetrahedron so you can do the same steps to the other side.**
5. **Now, add glue to the other flaps.**
6. **Fold these flaps over the straws.**
7. **See Figures 11, 12 and 13 shown below. This is how your tetrahedron should now look:**

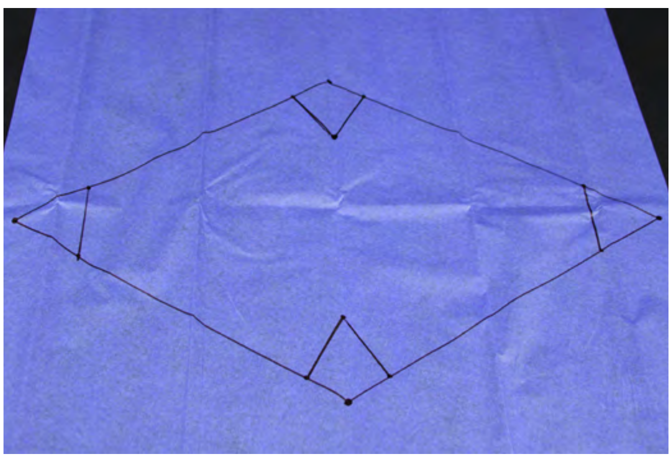


Fig. 11 Tissue paper template

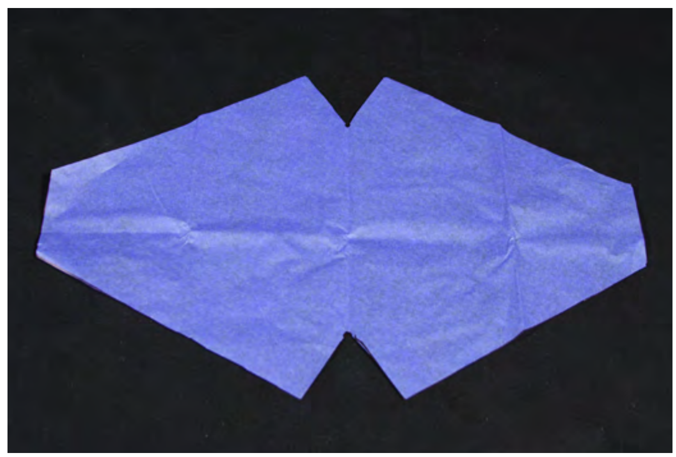


Fig. 12 Completed tissure paper template

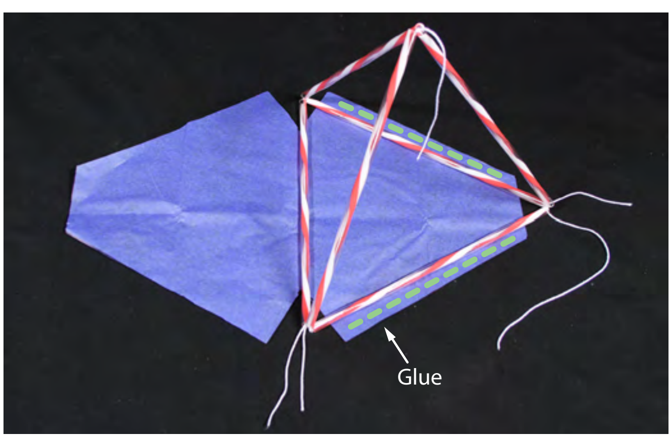


Fig. 13 Placement of tetrahedron on tissue paper template

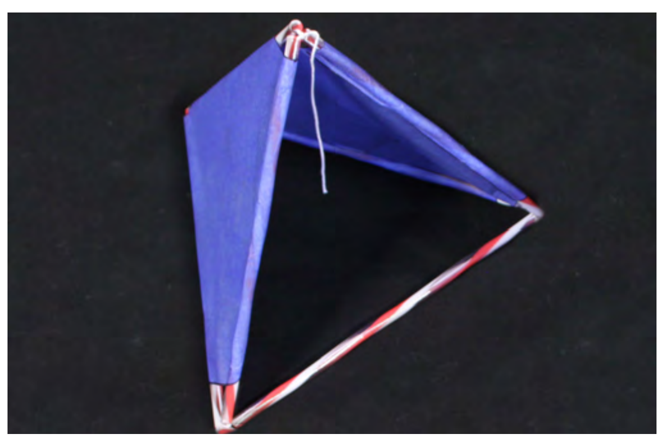


Fig. 14 Covered Tetrahedron

Worksheet 4 (cont.) Tetrahedral Kite

Section Six - Add Levels to the Tetrahedron

1. **Now that you have successfully created one tetrahedron, you will need to repeat Step One through Step Five to make an additional three tetrahedrons (four in total).**
2. **Once you have created the other three remaining tetrahedrons, choose three of them and place the tetrahedrons on a flat surface or table.**
3. **Each tetrahedron will have strings that are free. Use those free strings to tie one tetrahedron to another. This will tie the adjacent base vertices together. See picture below (fig. 14).**
4. **Now, take the fourth tetrahedron and place it on top of the other three that you have tied together. Tie the fourth tetrahedron to the adjacent vertices.**
5. **Note that all of your connections need to be tight so that there is not any slack in the string.**
6. **Now your tetrahedron should look like this: (See picture below, fig. 15).**
7. **As a team, decide how many more tetrahedrons you want to add to your kite before you decide to fly it. Repeat Step One through Step Five as necessary for your additions. Also, remember that when you add your additional tetrahedrons make sure the connections are tight.**

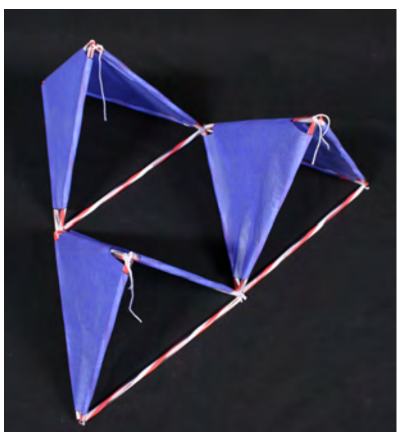


Fig. 15 Three tetrahedrons in the form of one large triangle

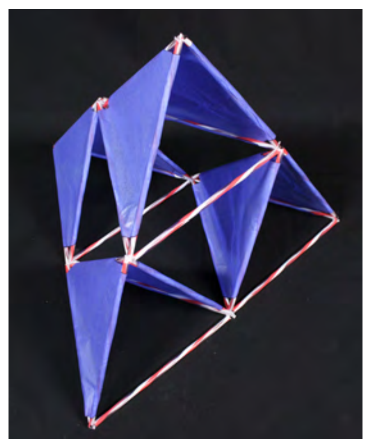


Fig. 16 Four Tetrahedrons

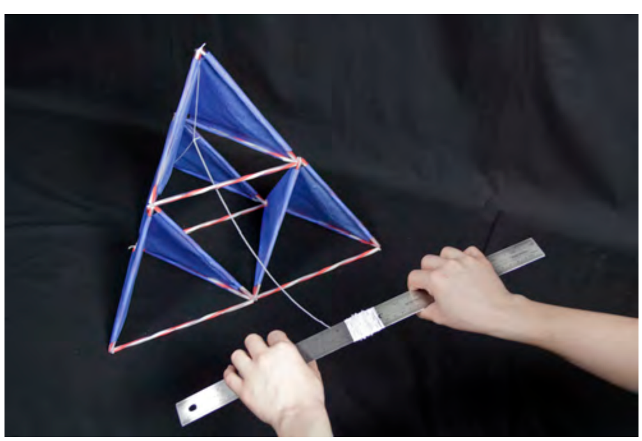


Fig. 17 Completed kite with bridle

Tetrahedral Kite

Section Seven - Build Your Bridle

1. **Now that you have made your kite, you will need to create and attach your bridle in order to fly it.**
2. **Tie your string (approximately 15 feet long) to the ruler so it can serve as your bridle.**
3. **Take your ruler to your teacher and he or she will use the hot glue gun to make sure your string stays on the ruler.**
4. **TEACHER: Take the hot glue gun and insert a glue stick. Plug the glue gun into the wall giving it time to heat up. Once the glue gun is ready, apply glue (approximately the size of the quarter) to the ruler in order to fasten the string to the bridle. Only when glue has cooled, return the glued ruler and string to the students.**
5. **Place your kite on the table with the base touching the table.**
6. **Next, tie a 24-inch string firmly to the very top of the kite.**
7. **Tie the same piece of string again to the middle joint. This will be between the top section of the kite and the bottom toward the front. There should not be any slack in the string.**
8. **Next, tie a loop in the middle of your string. The loop should be about the size of a quarter.**
9. **Now, attach the string of your kite to the loop.**
10. **Your kite is finished and ready to fly.**
11. **Complete the questions on your Kite Engineering Worksheet before attempting to fly your kite.**

Worksheet 4 (cont.) Tetrahedral Kite

Section Eight Questions

You have completed the final stages of constructing a tetrahedral kite. Now your team must decide how many layers to make your kite. Discuss and build your kite. When completed, please answer the following questions:

1. What is the ratio between covered sides and uncovered sides?

2. When you have assembled your kite, discuss what shapes are evident and list them below.

3. What is similar about the entire kite compared to the single tetrahedron you created earlier?

4. What is the ratio between covered cells and uncovered cells in the entire kite?

5. What is the surface area of the entire kite?

6. What is the volume of the entire kite?

7. What is the ratio between the surface area of a single cell compared to the entire kite?

8. What is the ratio between the volume of a single cell compared to the entire kite?

Tetrahedral Kite (Teacher Version)

Section One - Create a Tetrahedron Cell

1. **You will need the following supplies for this step: string, 6 straws (no longer than 8 inches long), scissors, and a flat surface.**
2. **First, cut a length of yarn/string four (4) feet long. (If the cut string has not already been provided.)**
3. **Second, take 6 straws and place them flat on the surface.**
4. **Use your piece of string to string 3 straws together. One end of the conjoined 3 straws should have two strings extended, 1) approximately 20 inches long, and 2) approx. 4 inches long.**
5. **Tie these two ends of the string tightly together to make sure that there is no room for the triangle to "wiggle."**
6. **The three straws should form a tight triangle.**
7. **There should be one a short and long piece of string now hanging off of the ends of two conjoined straws.**
8. **See fig. 2 as an example of a tight, three-straw triangle.**

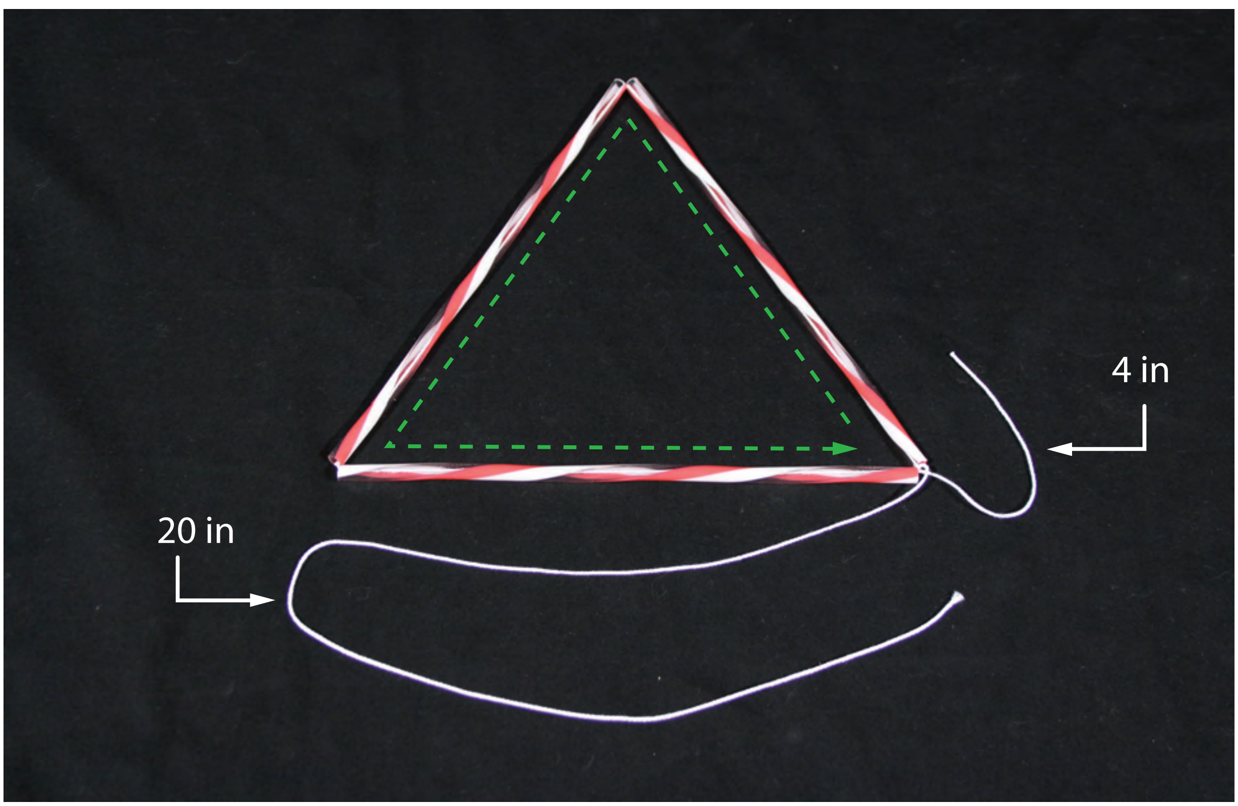


Fig. 2 Triangle

Worksheet 4 (cont.)

Tetrahedral Kite (Teacher Version)

Section One Questions & Answers

You have now completed the first part of constructing a tetrahedron. You have made a triangle connecting three straws. Record the following facts about the triangle:

1) Length of a side in inches = ______________________________
   (answers will vary based on the measurement of the length of the individual straw)

2) The measurement of each angle on the triangle = ______________________________

   Hint: 3 angles added together = 180°
   (60°)

3) Height of the triangle = ______________________________
   (8 inches)

4) Area of the triangle = ______________________________
   (27.7)

$$\text{Area} = \frac{s^2\sqrt{3}}{4}$$

5) All sides are equal ***or*** are not equal. (Circle one.)
   (Equal)

6) All angles are equal ***or*** are not equal. (Circle one.)
   (Equal)

7) This type of triangle is called an ______________________________ triangle.
   (Equilateral)

Section Two - Create a Rhombus

1. **The three straws should form a tight triangle.**

2. **Cut a10 cm piece of string and tie one end to any empty corner of the triangle.**

3. **Now, add 2 more straws onto the remaining longer end of the string.**

4. **Next, tie the long string to one end of the 10 centimeter string to form a rhombus.**

5. **See the picture below (fig. 3 & 4). Your rhombus should look like this.**

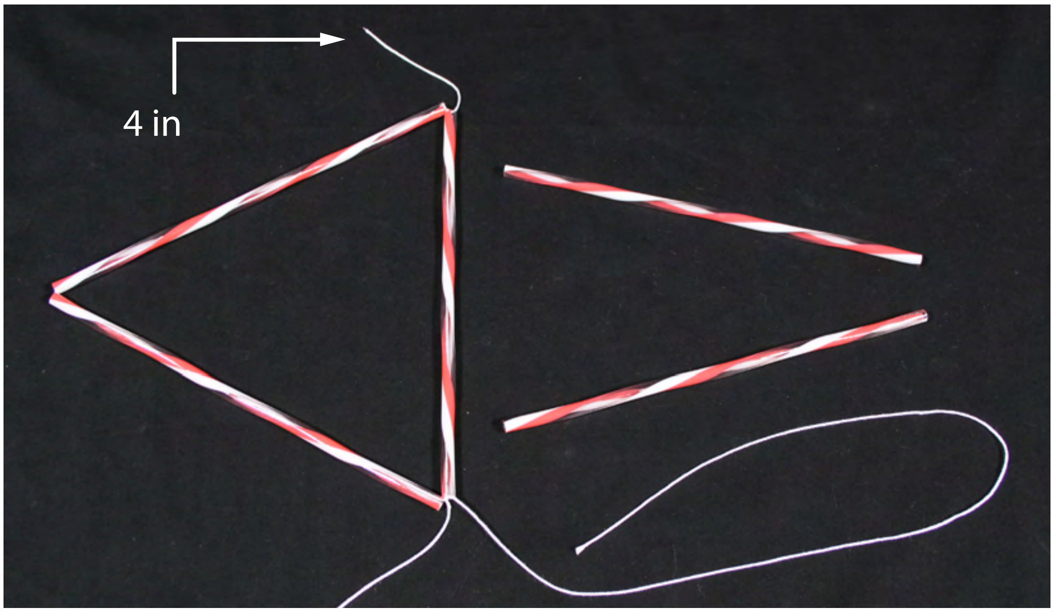


Fig. 3 Rhombus construction

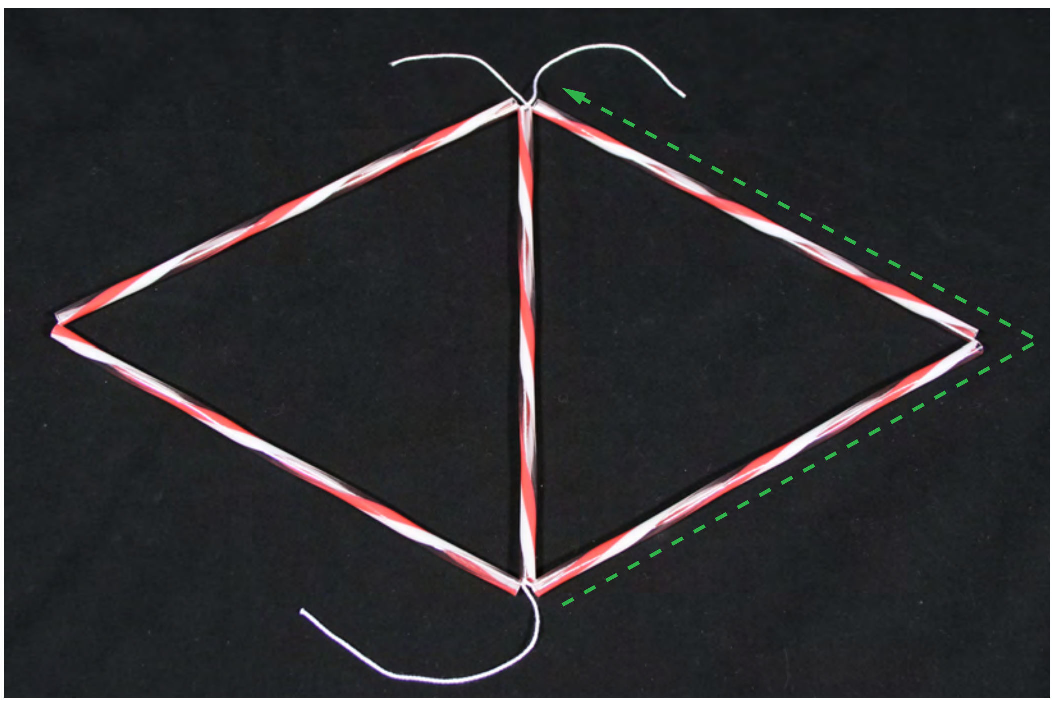


Fig. 4 **Completed** rhombus

Worksheet 4 (cont.) Tetrahedral Kite (Teacher Version)

Section Two Questions & Answers

You have now completed the second part of constructing a tetrahedron and have made a rhombus. Record the following facts about the rhombus:

1) Length of a side in inches = ______________________________
   (answers will vary based on the measurement of the length of the individual straw)

2) The measurement of each angle in the rhombus = __*(60°)*__ __*(60°)*__ __*(120°)*__ __*(120°)*__

   Hint: 4 angles added together = 360°
   (60°) (60°) (120°) (120°)

3) Height of the rhombus = ______________________________
   (answers will vary based on the measurement of the length of the individual straw)

4) Area of the rhombus = ______________________________
   (answers will vary based on the measurement of the length of the individual straw)

5) All sides are *equal* ***or*** are not equal. (Circle one.)

6) All angles are *equal* ***or*** are not equal. (Circle one).

Section Three - Create a Three Dimensional Tetrahedron

1. **Cut a piece of string that is double the length of one straw (or side of a tetrahedron).**
2. **Tie one end of that string to one of the remaining empty corners.**
3. **Cut another piece of string 10 centimeters long.**
4. **Take that shorter piece of string and tie one end to the other empty corner.**
5. **Now, string the last straw onto the longer piece of string.**
6. **Tie the two opposite sides together.**
7. **See the picture below (fig. 5 & 6). Your tetrahedron should look like this:**

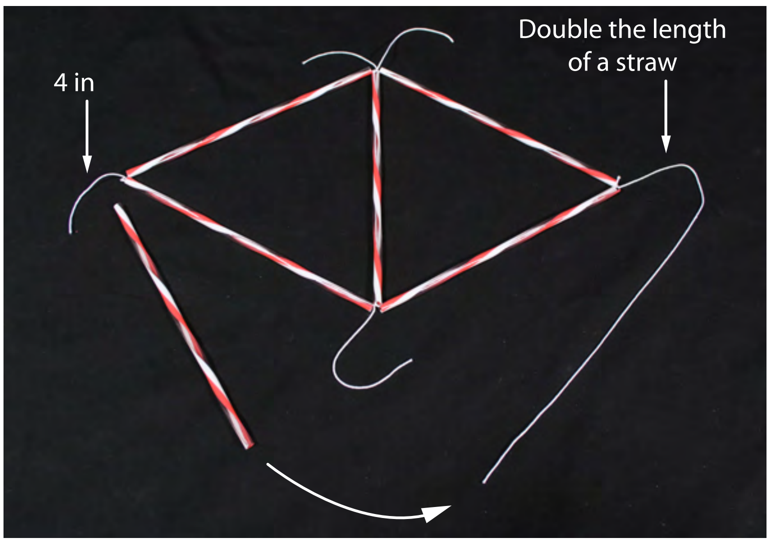


Fig. 5 Three dimensional tetrahedron construction

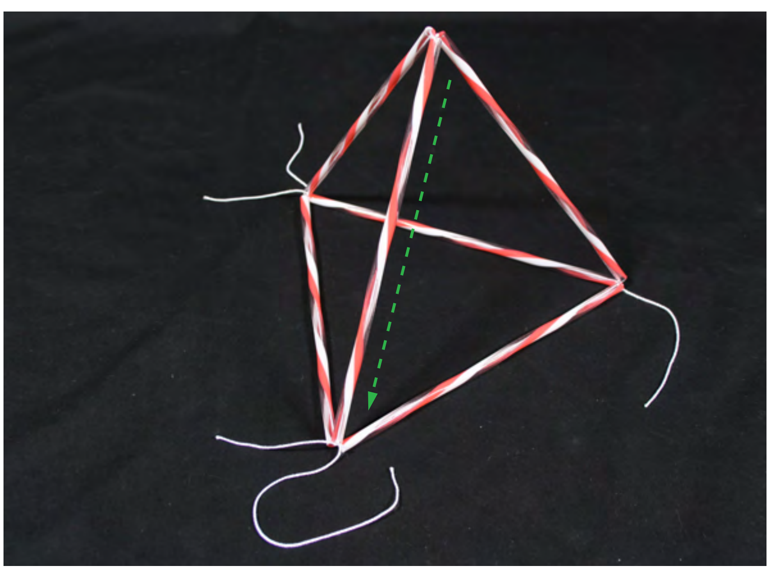


Fig. 6 Completed three dimensional tetrahedron

Worksheet 4 (cont.)

Tetrahedral Kite (Teacher Version)

Section Three Questions & Answers

You have now completed the third set of steps and have constructed a tetrahedron! Record the following facts about the tetrahedron:

1) How many triangular faces does it have? ___*(4)*___

2) What is the volume? ________________________________

Hint: First you must find the area of the base.

That formula is A = ½ x base x height

Hint: The formula for finding the volume is

V = 1/3 x (area of the base) x height

(answers will vary based on the measurement of the lengths of the individual straws)

Tetrahedral Kite (Teacher Version)

Section Four - Create a Tetrahedron Tissue Paper Cover

1. **Remember to pay attention to the length of the straws as the template may be different and may need to be adjusted in size since straws come in a variety of lengths.**
2. **Choose a piece of colored tissue paper.**
3. **Fold the paper so that it will fill the template shown on your worksheet.**
4. **Be sure to place the widest edge on the fold.**
5. **Now trace around the edges lightly with a pen or pencil.**
6. **Cut out the pattern that you just traced and open it.**
7. **See the picture below (fig 7, 8, 9 & 10). Your tissue paper should look like this:**

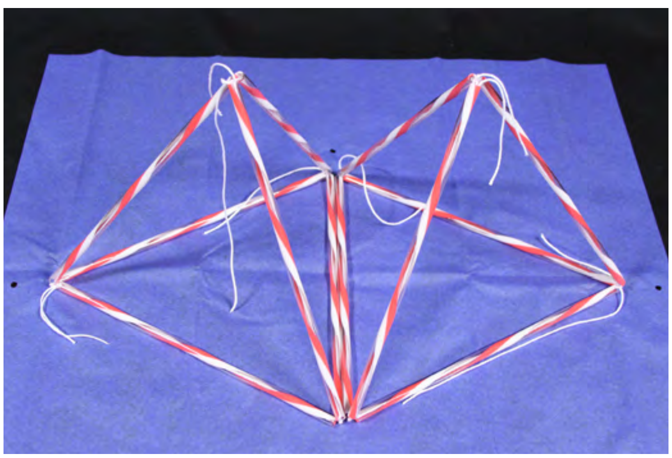


Fig. 7 One-inch marks to create template

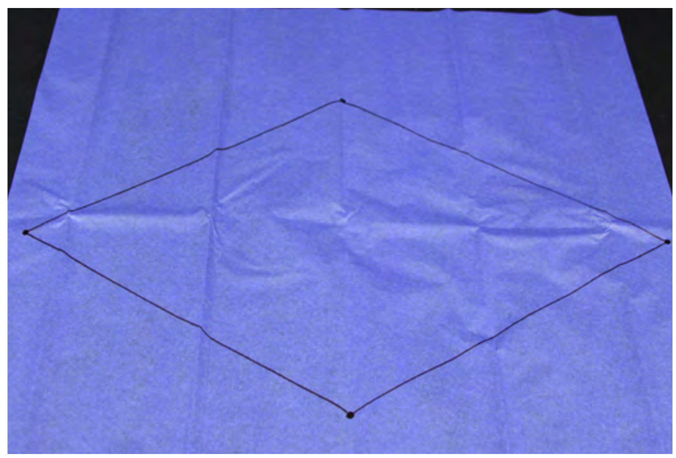


Fig. 8 Template construction

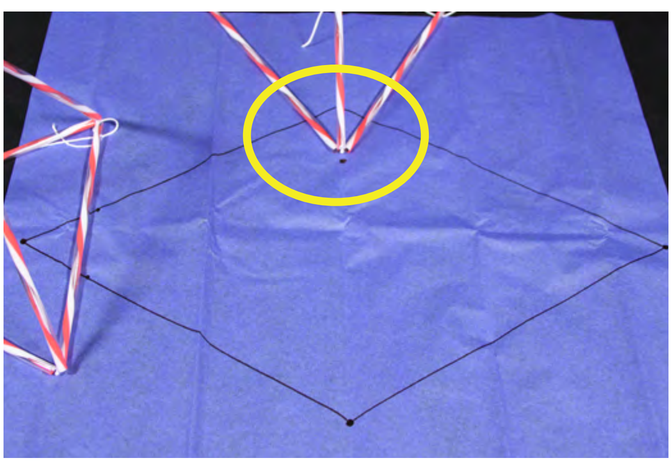


Fig. 9 Obtuse angle marking for template construction

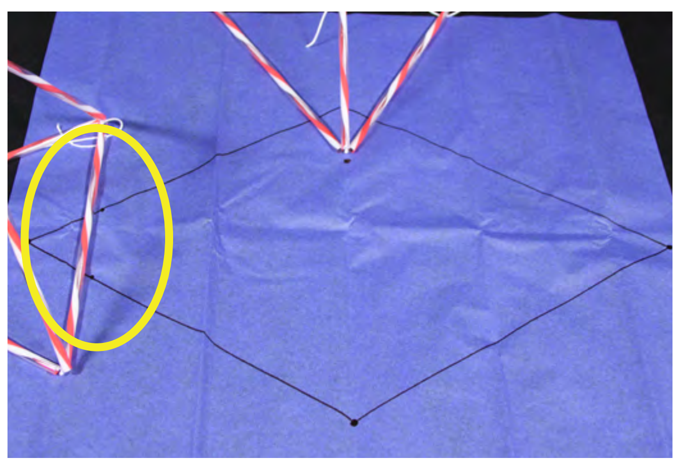


Fig. 10 Acute angle marking for template construction

Worksheet 4 (cont.)

Tetrahedral Kite (Teacher Version)

Section Five - Cover the Tetrahedron

1. **Lay the tissue paper on your table.**
2. **Wrap the tissue paper around the two sides of the tetrahedron.**
3. **Now glue the tabs using a glue stick and fold them around the straws. (Spread the glue along the flaps and fold the flaps over the straws.) Make sure that it is a tight fit.**
4. **Rotate the tetrahedron so you can do the same steps to the other side.**
5. **Now, add glue to the other flaps.**
6. **Fold these flaps over the straws.**
7. **See Figures 11, 12, and 13 shown below. This is how your tetrahedron should now look:**

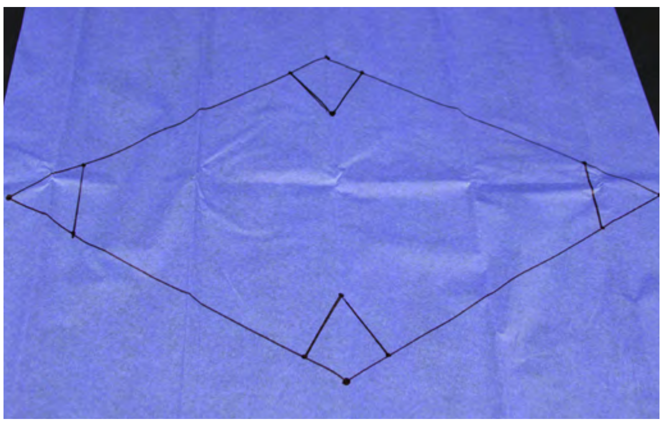


Fig. 11 Ttissue paper template

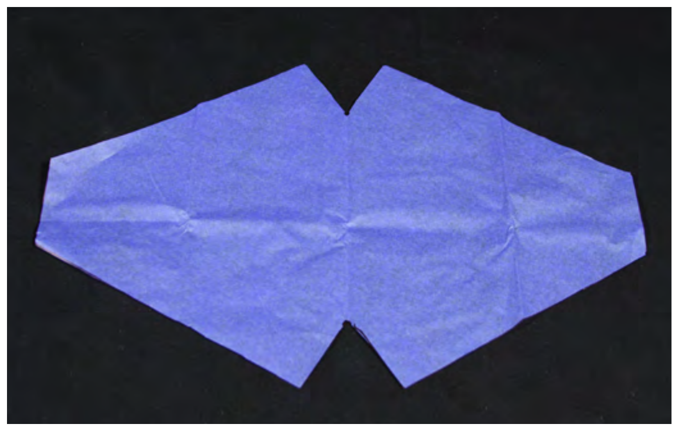


Fig. 12 Completed tissue paper cover

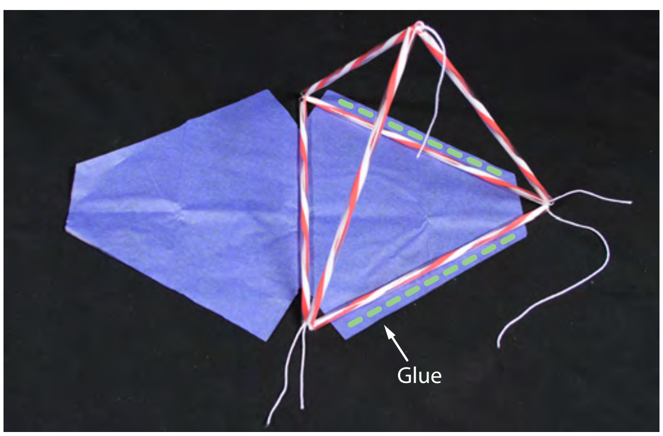


Fig. 13 Placement of tetrahedron on tissue paper template

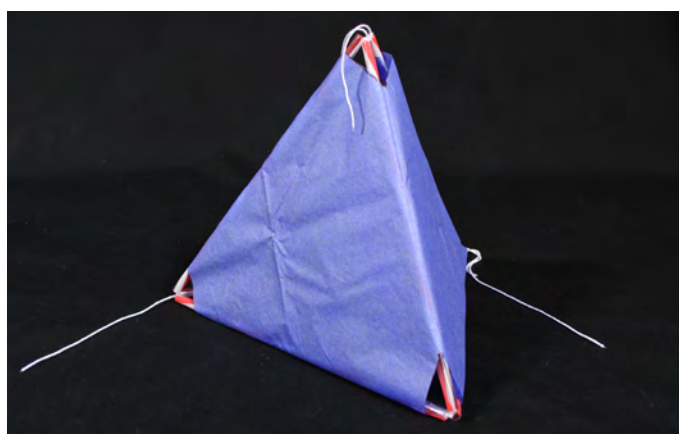


Fig. 14 Covered Tetrahedron

Section Six - Add Levels to the Tetrahedron

1. **Now that you have successfully created one tetrahedron, you will need to repeat Step One through Step Five to make an additional three tetrahedrons (four in total).**
2. **Once you have created the other three remaining tetrahedrons, choose three of them and place the tetrahedrons on a flat surface or table.**
3. **Each tetrahedron will have strings that are free. Use those free strings to tie one tetrahedron to another. This will tie the adjacent base vertices together. See picture below (fig. 14).**
4. **Now, take the fourth tetrahedron and place it on top of the other three that you have tied together. Tie the fourth tetrahedron to the adjacent vertices.**
5. **Note that all of your connections need to be tight so that there is not any slack in the string.**
6. **Now your tetrahedron should look like this: (See picture below, fig. 15).**
7. **As a team, decide how many more tetrahedrons you want to add to your kite before you decide to fly it. Repeat Step One through Step Five as necessary for your additions. Also, remember that when you add your additional tetrahedrons make sure the connections are tight.**

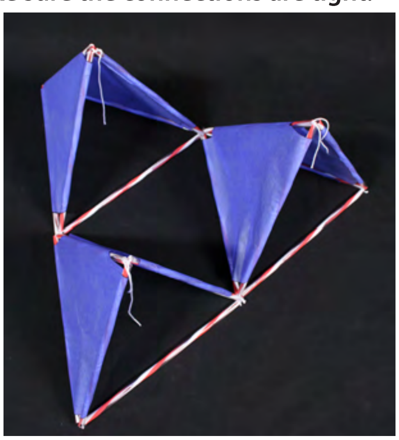


Fig. 15 Three tetrahedrons in the form of one large triangle

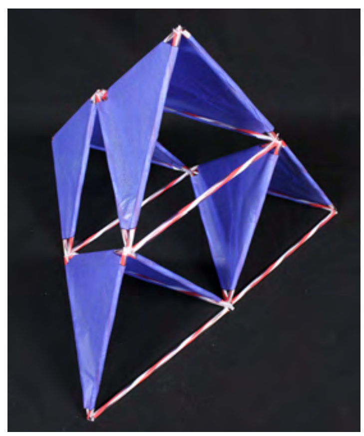


Fig. 16 Four tetrahedrons

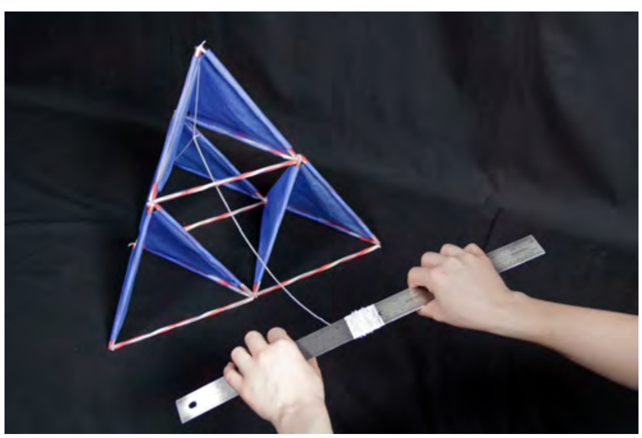


Fig. 17 Completed kite with bridle

Worksheet 4 (cont.) Tetrahedral Kite (Teacher Version)

Section Seven - Build Your Bridle

1. **Now that you have made your kite, you will need to create and attach your bridle in order to fly it.**
2. **Tie your string (approximately 15 feet long) to the ruler so it can serve as your bridle.**
3. **Take your ruler to your teacher and he or she will use the hot glue gun to make sure your string stays on the ruler.**
4. **TEACHER: Take the hot glue gun and insert a glue stick. Plug the glue gun into the wall giving it time to heat up. Once the glue gun is ready, apply glue (approximately the size of the quarter) to the ruler in order to fasten the string to the bridle. Only when glue has cooled, return the glued ruler and string to the students.**
5. **Place your kite on the table with the base touching the table.**
6. **Next, tie a 24-inch string firmly to the very top of the kite.**
7. **Tie the same piece of string again to the middle joint. This will be between the top section of the kite and the bottom toward the front. There should not be any slack in the string.**
8. **Next, tie a loop in the middle of your string. The loop should be about the size of a quarter.**
9. **Now, attach the string of your kite to the loop.**
10. **Your kite is finished and ready to fly.**
11. **Complete the questions on your Kite Engineering Worksheet before attempting to fly your kite.**

Section Eight Questions & Answers

You have completed the final stages of constructing a tetrahedral kite. Now your team must decide how many layers to make your kite. Discuss and build your kite. When completed, please answer the following questions:

1) What is the ratio between covered sides and uncovered sides?
(1:1)

2) When you have assembled your kite, discuss what shapes are evident and list them below.
(Answers should include triangles, equilateral triangles, rhombus, tetrahedron)

3) What is similar about the entire kite compared to the single tetrahedron you created earlier?
(Answer should include one cell builds on another cell to create a tetrahedron)

4) What is the ratio between covered cells and uncovered cells in the entire kite?
(The ratio needs to be equal like 1:1 but the student answers will vary based on the layers they decided to build on the kite. They will need to count the covered cells to uncovered cells to get the answer.)

5) What is the surface area of the entire kite?
(Answers will vary based on how big their kite is.)

6) What is the volume of the entire kite?
(Answers will vary based on how big their kite is.)

7) What is the ratio between the surface area of a single cell compared to the entire kite?
(Answers will vary based on how big their kite is.)

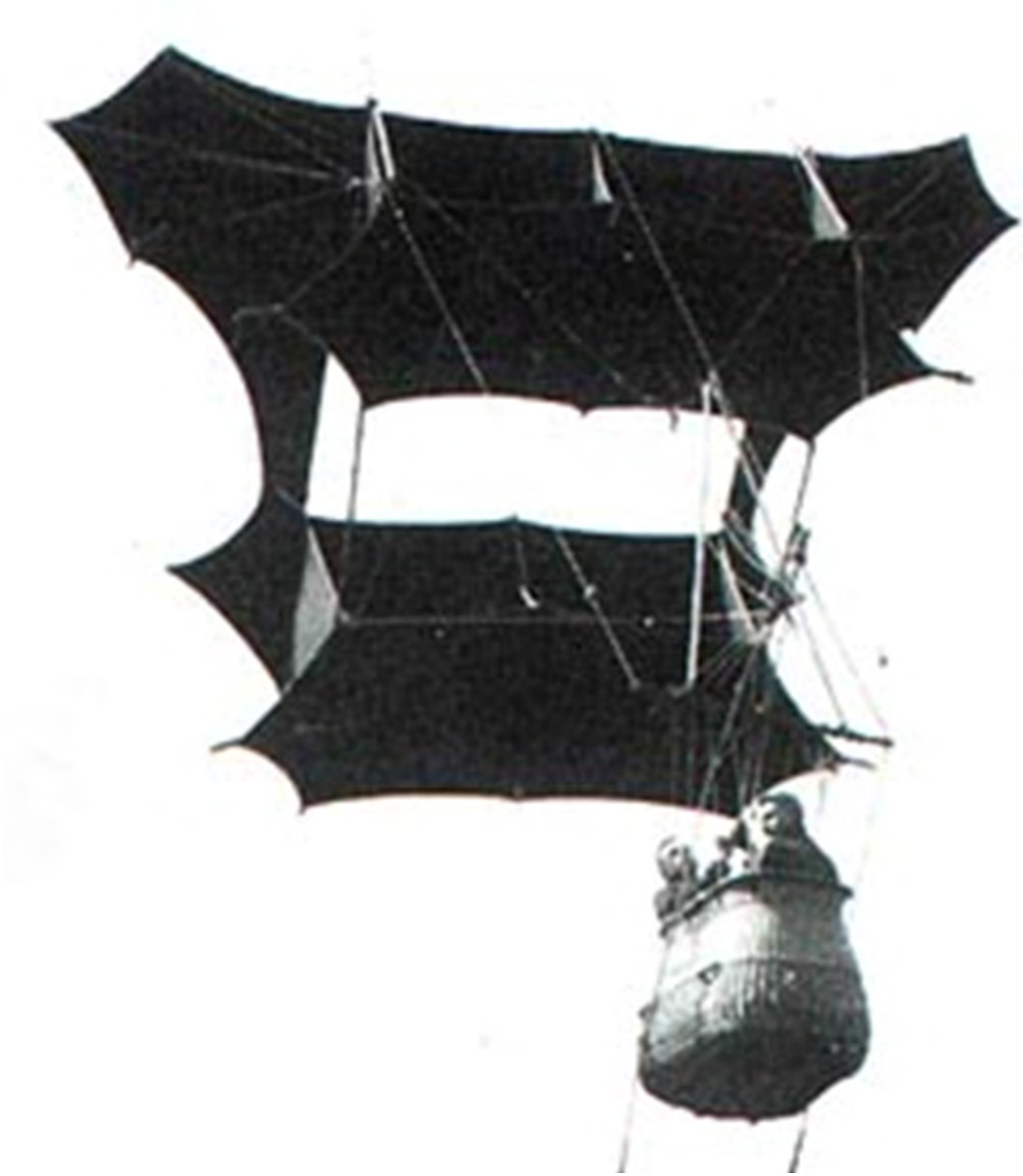
8) What is the ratio between the volume of a single cell compared to the entire kite?
(Answers will vary based on how big their kite is.)

Images

Img. 1 Children flying kites

(Public Domain)

Img. 2 Cody manlifter



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Img. 3 Samuel Cody

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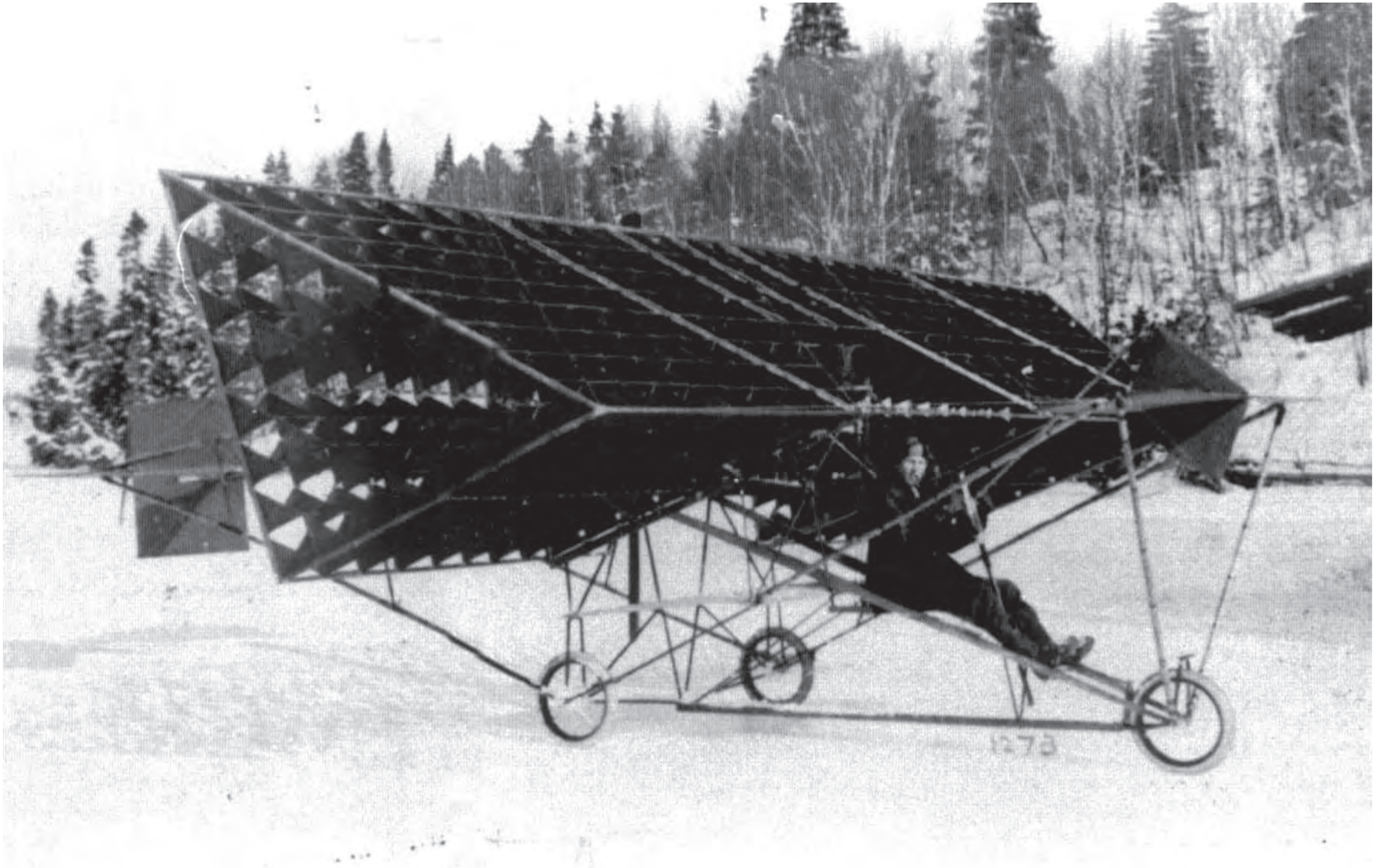
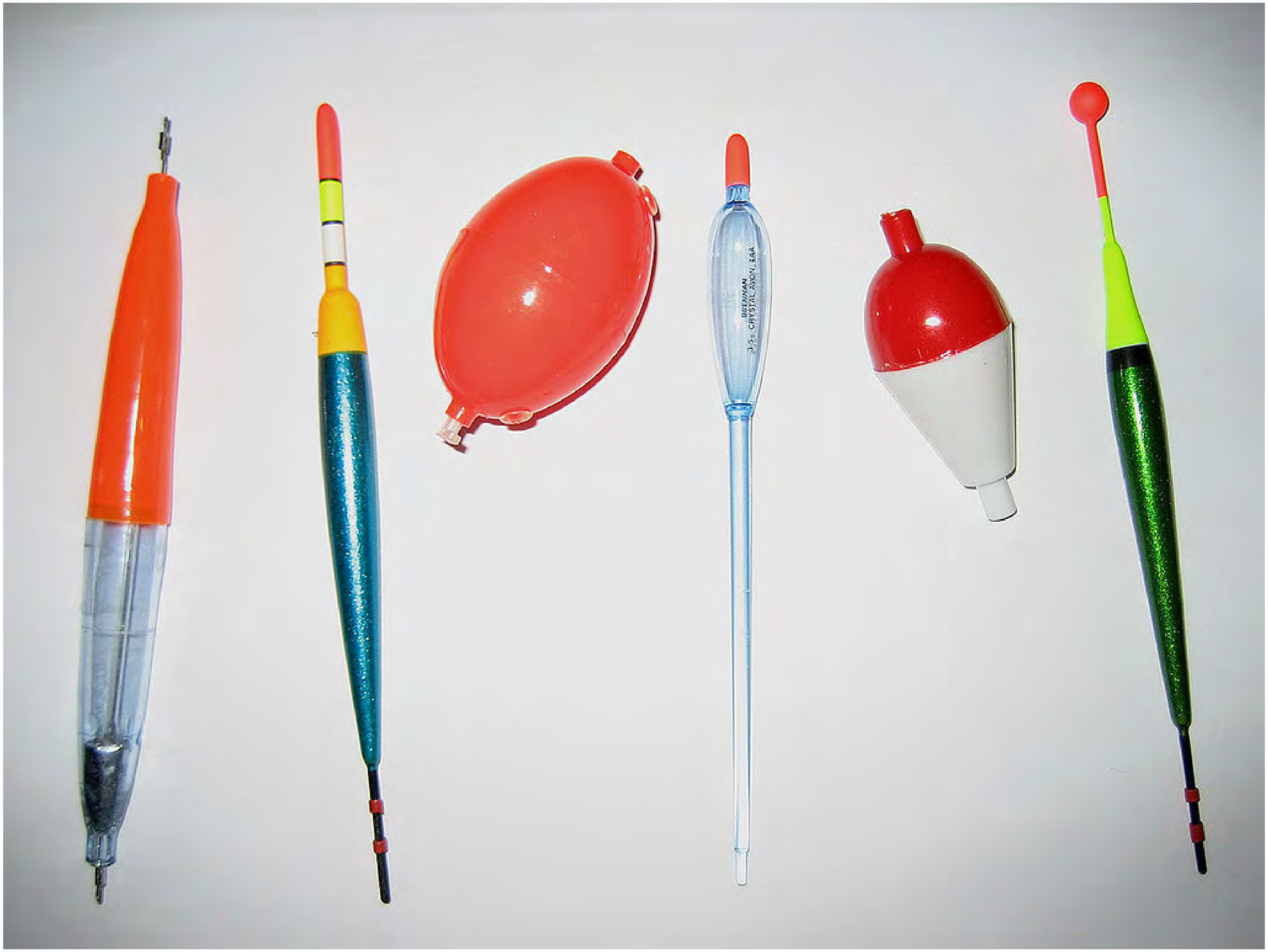
Img. 4 Bell's tetrahedron kite



(Photo courtesy of NASA)

Img. 5 Fishing bobbers



(Public Domain)

Img. 6 Kite fishing

(Public Domain)

Img. 7 Scarecrow

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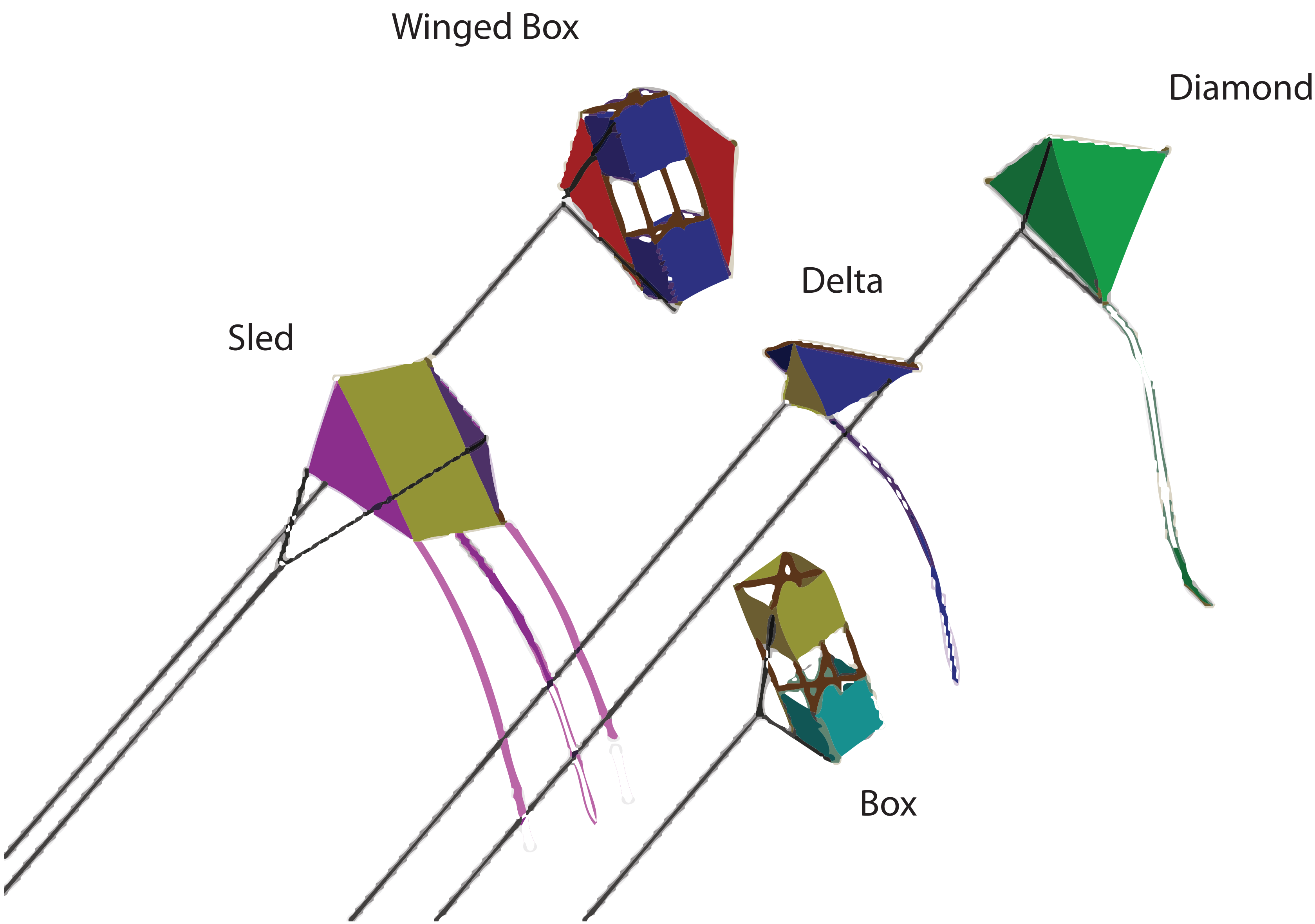
Img. 8 A modern kite

(Photo courtesy of Shari Weinsheimer via PublicDomainPictures.net)

Img. 9 Types of kites



(Photo courtesy of NASA)

Img. 10 Benjamin Franklin flying his kite

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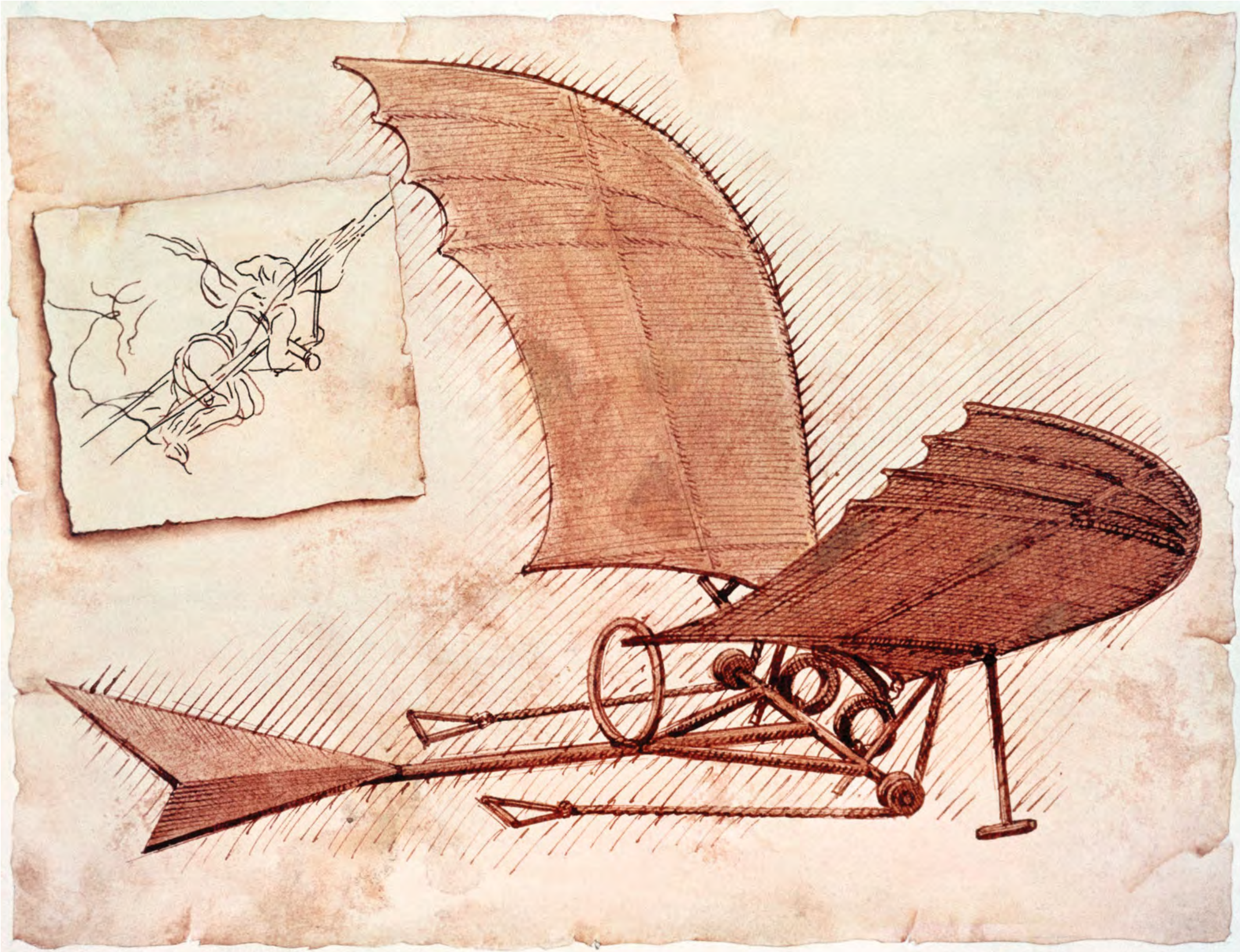
Img. 11 Leonardo da Vinci's Ornithopter



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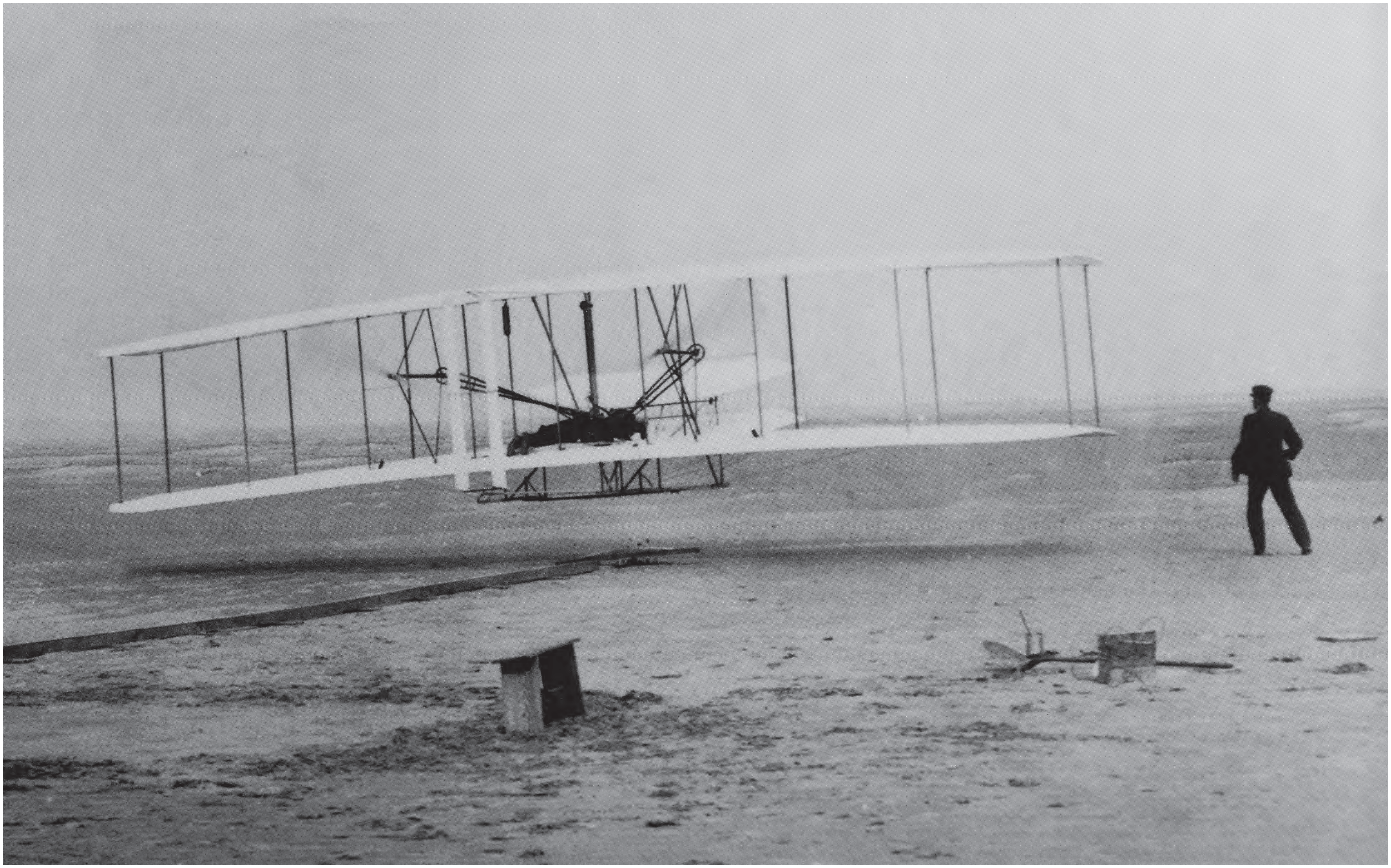
Img. 12 Wright flyer



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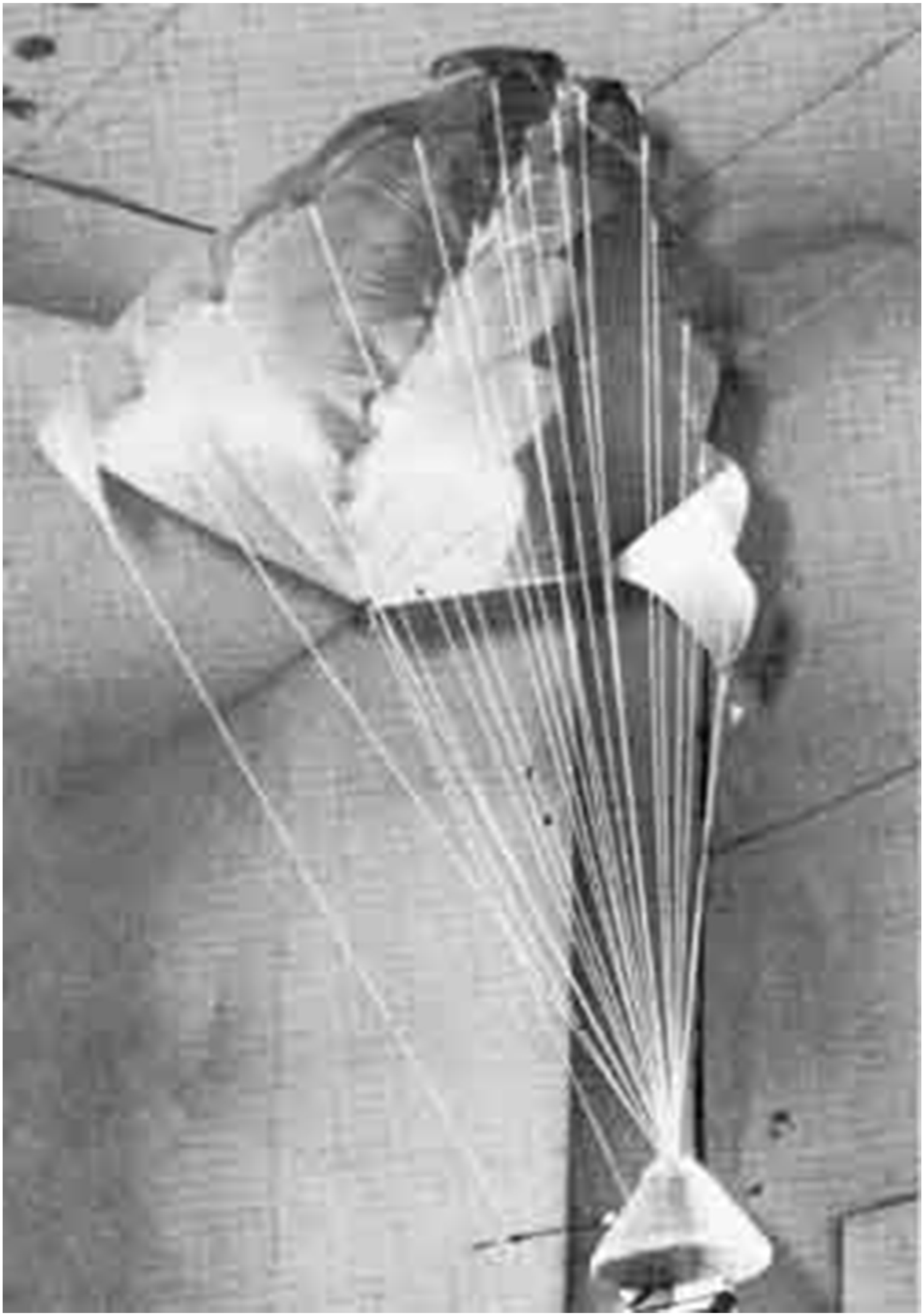
Img. 13 Rogallo's wing



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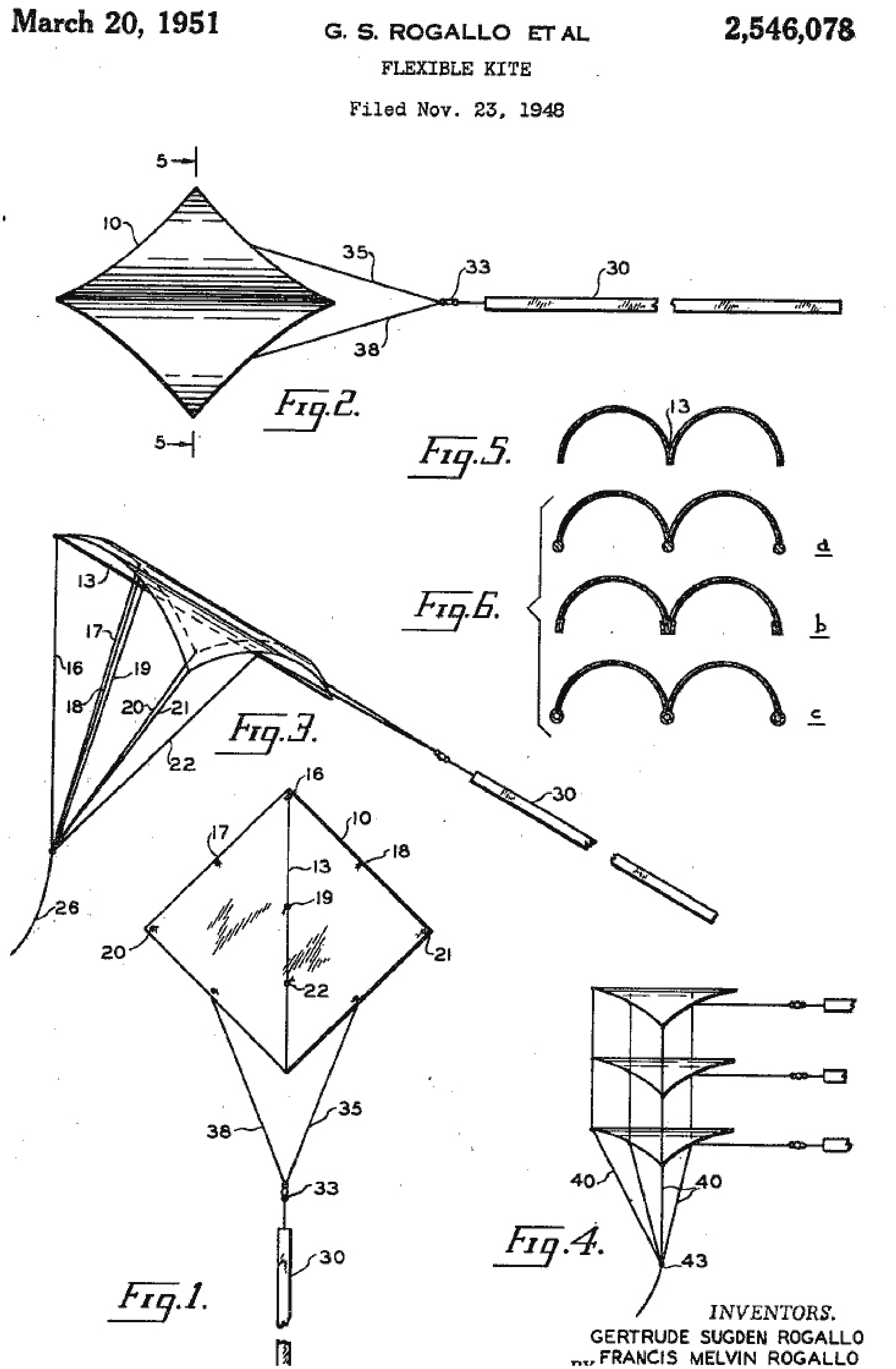
Img. 14 Rogallo patent



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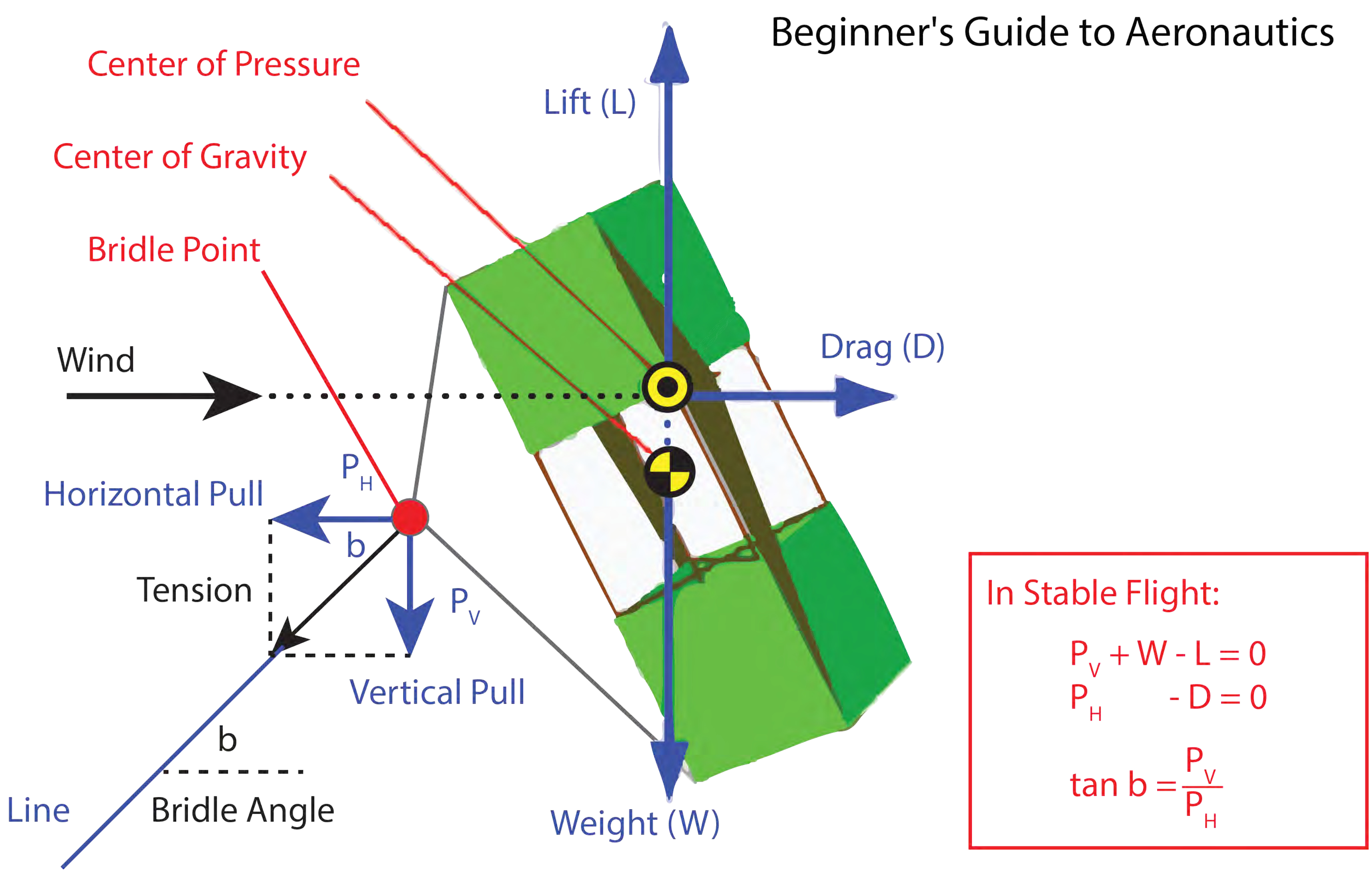
Img. 15 Forces on a kite



(Photo courtesy of NASA)

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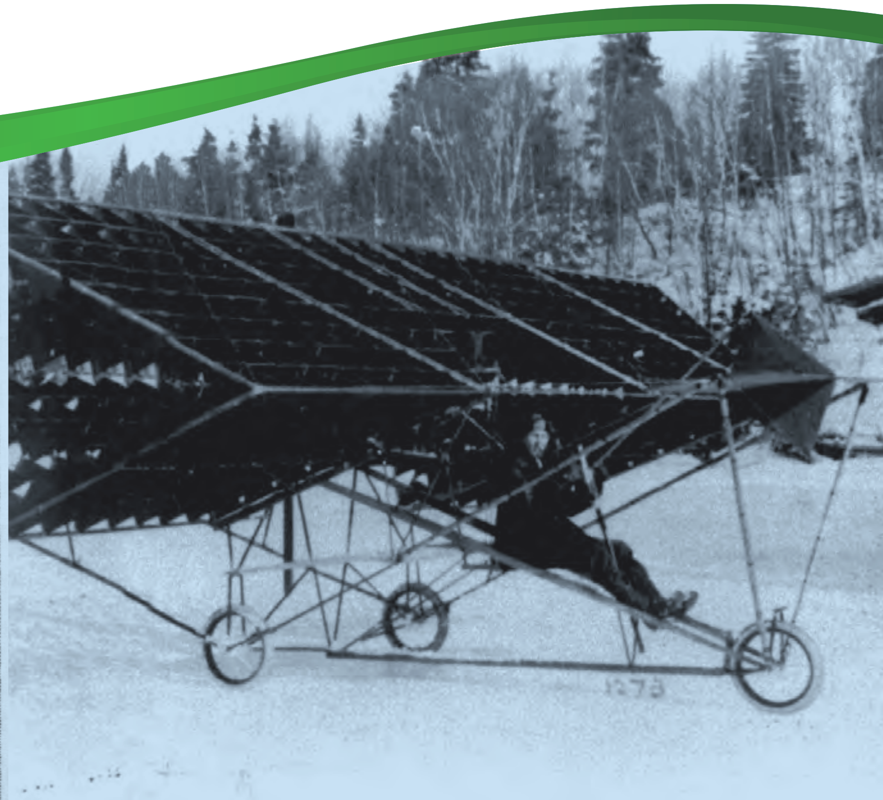

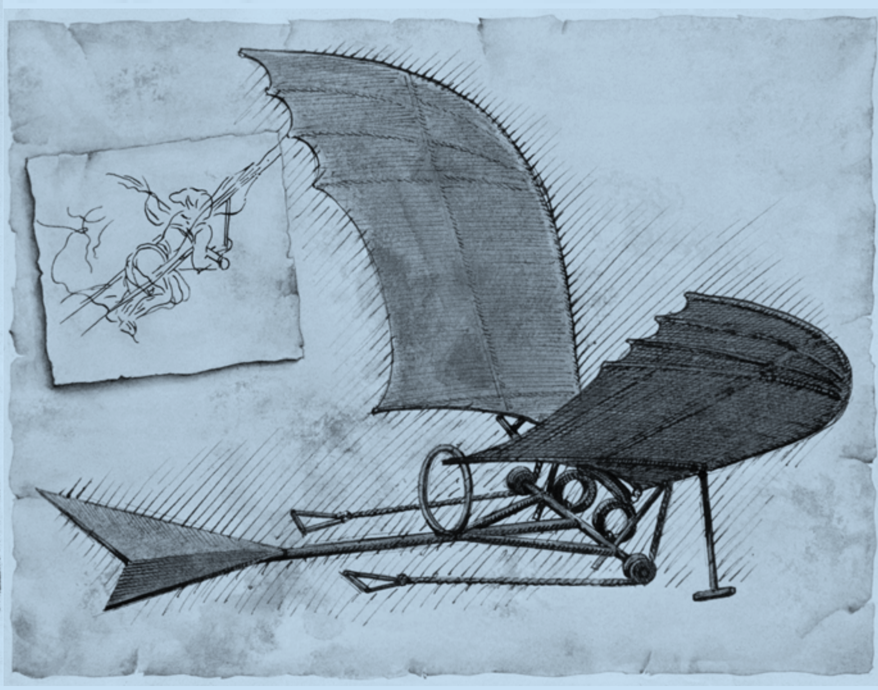

principles of flight

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