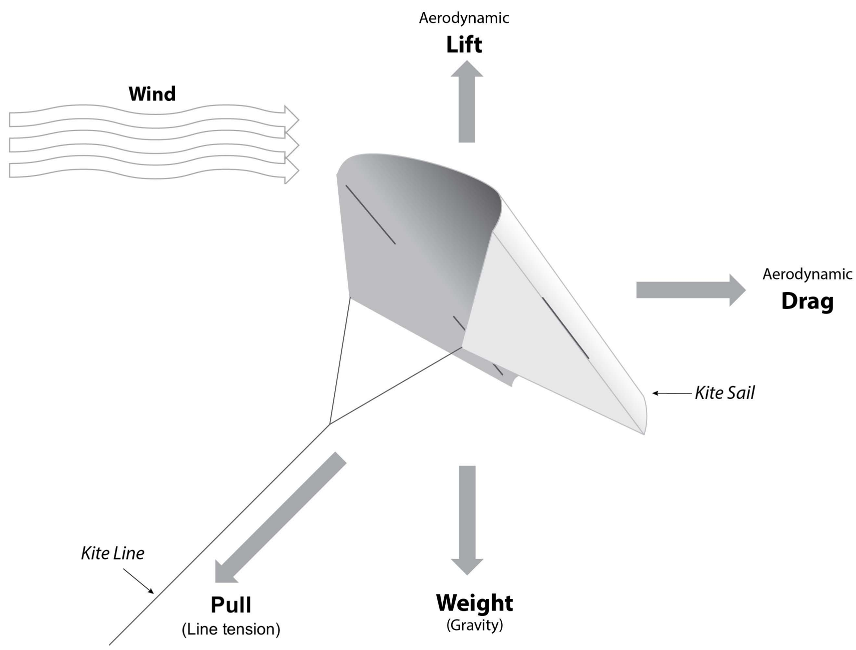
BACKGROUND

Aerodynamics

Four forces act on a kite in flight:

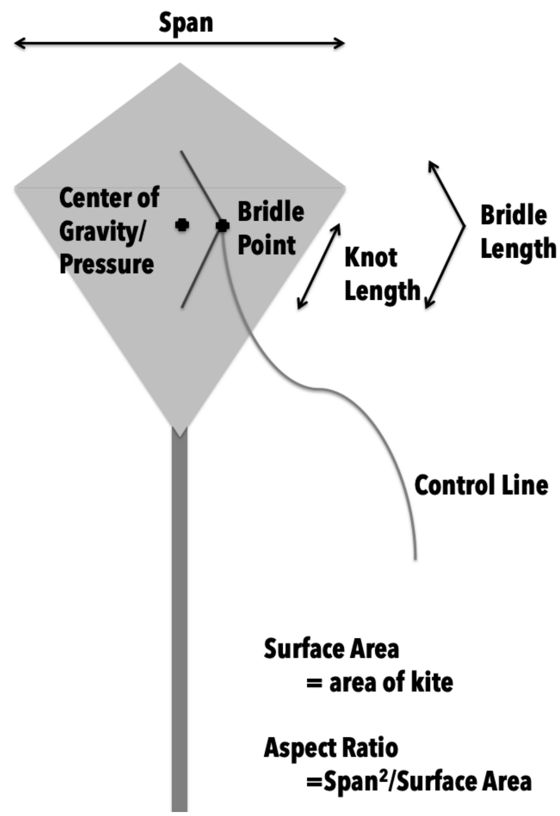
- Lift- the force that acts in the opposite direction of the ground. The kite must overcome the weight of the kite itself and the force of gravity in order to fly.
- Drag- the force of wind pushing on the kite. Drag is a type of friction that depends on both the velocity and density of the wind.
- Weight- the force that pulls the kite towards the ground and is made up in part by gravity.
- Pull- the force of tension on the kite line. Pull is the tension on the kite line caused by the operator holding the line that keeps the kite from being taken away by the wind.



When the kite is in stable flight the forces remain constant. In the vertical direction, the sum of the forces is zero. So, the vertical pull plus the weight minus the lift is equal to zero. In the horizontal direction, the sum of the horizontal pull and the drag must also equal zero.

Kite Geometries

The success of a kite is largely determined by the geometries of the kite. On a typical diamond kite, several design factors allow it to fly, including the size and dimensions of the kite, as well as the angle it flies. The **span** is the widest distance from side to side, similar to the wing span of an airplane: the distance from one wing tip to the other wing tip. Similarly, the **surface area** of the kite is determined by calculating the total surface of the kite. The ratio of the square of the span to the area A is called the **Aspect Ratio**, AR, of the kite.



This parameter is very important in the determination of lift and drag of the kite. The **center of gravity** is the average location of the weight of the kite, and the weight force acts through this point. Similarly, the **center of pressure** is the average location of the aerodynamic forces on the kite, and the lift and drag act through this point. On the front of the kite we attach a **bridle string.** The **bridle length** is the length of the string from one end attached to the top to the other end attached to the bottom of the kite. It is always longer than the height of the kite, so there is some slack in this string. A knot is used to attach the **control line** to the bridle at a spot called the **bridle point.** The **knot length** is the distance from the bottom to the knot along the bridle string. The knot length and the bridle length determine the location of the bridle point. In flight, the kite rotates about the bridle point. A kite's stability is determined by the forces on the kite and the location of the bridle point.

Although miniature kites are much smaller than the average kite, they abide by similar rules when designing. One area of difference is material selection. When designing miniature kites it is much more important to use lightweight materials, because the small surface area cannot generate a lot of lift, so in order for miniature kites to fly they must be incredibly light.

Wind

Wind is the flow of air on a large scale caused by differences in atmospheric pressure. It's characterized in meteorology by velocity and density. When a difference in atmospheric pressure exists, air moves from the higher to the lower pressure area, resulting in winds of various speeds. Wind occurs on a range of scales, from thunderstorm flows lasting tens of minutes, to local breezes generated by heating of land surfaces and lasting a few hours, to global winds resulting from the difference in absorption of solar energy between the climate zones on Earth. The two main causes of large-scale atmospheric circulation are the difference in heating between the equator and the poles, and the rotation of the planet (Coriolis effect). One way to characterize wind speeds is with the Beaufort Scale that associates wind ranges with the effect on the local land condition.

Appropriate wind conditions are crucial for successful kite flying. Most kites come labeled with an ideal wind range that is safe and appropriate for that specific kite. Flying in speeds under the ideal wind range means the kite will not be able to generate enough lift to fly, and above the wind range the kite will fly erratically and can become dangerous to the flyer.

Design a Mini Kite

Overview

Students will follow an instruction sheet to create a standard miniature kite. They will record observations of how the kite flies and hypothesize what attributes of the kite make it a successful design. In Part 2, the Design Challenge, students will design and create their own miniature kites and record their observations of the flight, including why their kite was/was not successful and how it was different from the first design. Students can work in groups of 4-5 to identify the design that flew most successfully and discuss why it was a successful design.

Objective

Introduce the concepts of aerodynamics and wind and how they influence kite flight. Encourage the students to make and record critical observations about what factors contribute to a successful kite. Further expand the activity into a design challenge to exercise their creativity and what they've learned about aerodynamics.

Time

Part 1: Standard miniature kite design

Introduction to aerodynamics: 15 minutes

First construction: 15 minutes

Data recording: 10 minutes

Part 2: Design Challenge

Design and construction: 30 minutes

Discussion and data recording: 20 minutes

Materials

Part 1 – Standard Kite

- Tissue Paper
- Scissors
- Rulers
- Pens
- Pencils
- Small Stickers or Tape
- Thread
- Optional: Large straws or sticks

Part 2 – Design Challenge

- Variety of paper (wrapping paper, copy paper, etc.)
- Variety of tail materials (streamers, ribbon,tissue paper, tinsel, etc.)

Age Group

Most appropriate for 4-8 grade level

Preparation

- Make one standard kite to show as an example and practice lofting it through the air
- If under a time constraint or working with younger children, consider cutting out the tissue paper kite body and tails beforehand
- Make copies of the mini kite diagram as well as the science observation sheets
- Plan for how to organize students into groups of 4 or 5

Standard miniature kite Instructions (Diagram p. 13)

1. Cut out a piece of tissue paper to size 2x3" for kite body and two tails ¼x12"
2. Cut a 24" piece of thread
3. Fold the kite body in half lengthwise
4. Measure ¾" from the top of the kite along the fold and draw a dot
5. Using the tape/sticker, attach the thread to the kite at the dot from previous step
6. Use two more pieces of tape/stickers to attach the two tails at the corners opposite the end with the thread (reference diagram for final assembly)
7. Hold the end of the thread and gently wave the kite back and forth through the air to fly. (Optional: Attach the thread to the large straw or stick) If the kite is built to the standards on the instruction sheet, it will loft into the air.

Collecting and Recording Data

After the mini kite is assembled and flown, each student should write down observations on their data sheets explaining how the kite flew and hypothesizing what characteristics of the kite allow it to fly well.

Technology

To briefly summarize the mechanics of this type of kite, the mini kite is successful because of the ultralight material. With such a small surface area to capture wind, the kite would need to have tremendous lifting power to lift the weight of heavier kite materials. The tails are lightweight for the same reason, but they are also long to introduce weight and drag to the lower end of the kite and create stability in the kite so it flies smoothly. Similarly, the fold in the standard mini kite is not 100% necessary but it makes for a much smoother flying kite because the angle, or dihedral, created by the fold allows the wind to catch both sides of the kite equally. If the kite rotates in flight, the wind will push harder on the forward most side to return it back to equilibrium. Miniature kites are beholden to the same laws of aerodynamics as larger kites, meaning the size and shape as well as bridle position and tails are really important components that determine how well a kite flies. And most important of all, wind! Without the right amount of air movement, miniature or regular kites will not fly.

Part 2: Design Challenge

Once the students have created the standard mini kite and have had a chance to analyze and record the flight and kite attributes, we encourage the activity be taken a step further to incorporate a design challenge. Provide the students with a variety of materials for use in kite creation, such as wrapping paper, printer paper, toothpicks, ribbon, trash bags, etc. The students will take a couple minutes to brainstorm ideas for their own mini kite designs, draw out the designs, and make note of how their design is different from the original design and how they think it will perform in comparison. Depending on the age group, it might be appropriate for the students to first brainstorm and draw out their design ideas and have them approved by the instructor before they start working towards building the mini kite.

After constructing and test flying the kites, they will make another observation, detailing what aspects of the kite they changed, how they expected the changes to affect the kite flight, and what happened in reality. They will note the kite's performance and why they think it performed better or worse than the standard kite. In groups of 4 or 5, students decide who created the most successful design and discuss why it flew well. One group representative should present the design to the class and explain why they believed it was successful. The class as a whole can then discuss their observations and what worked best and why to create a better understanding of aerodynamics in practice.

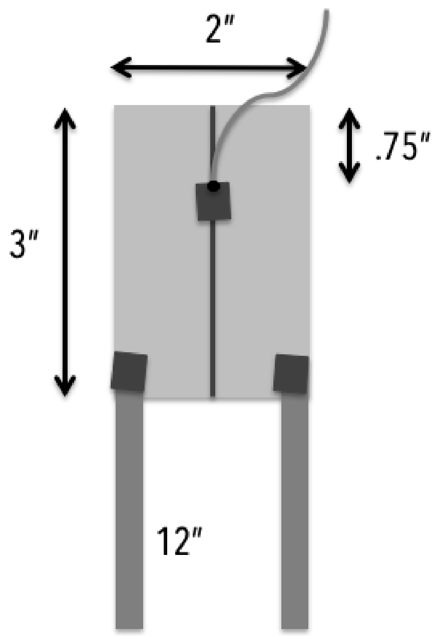
Operations

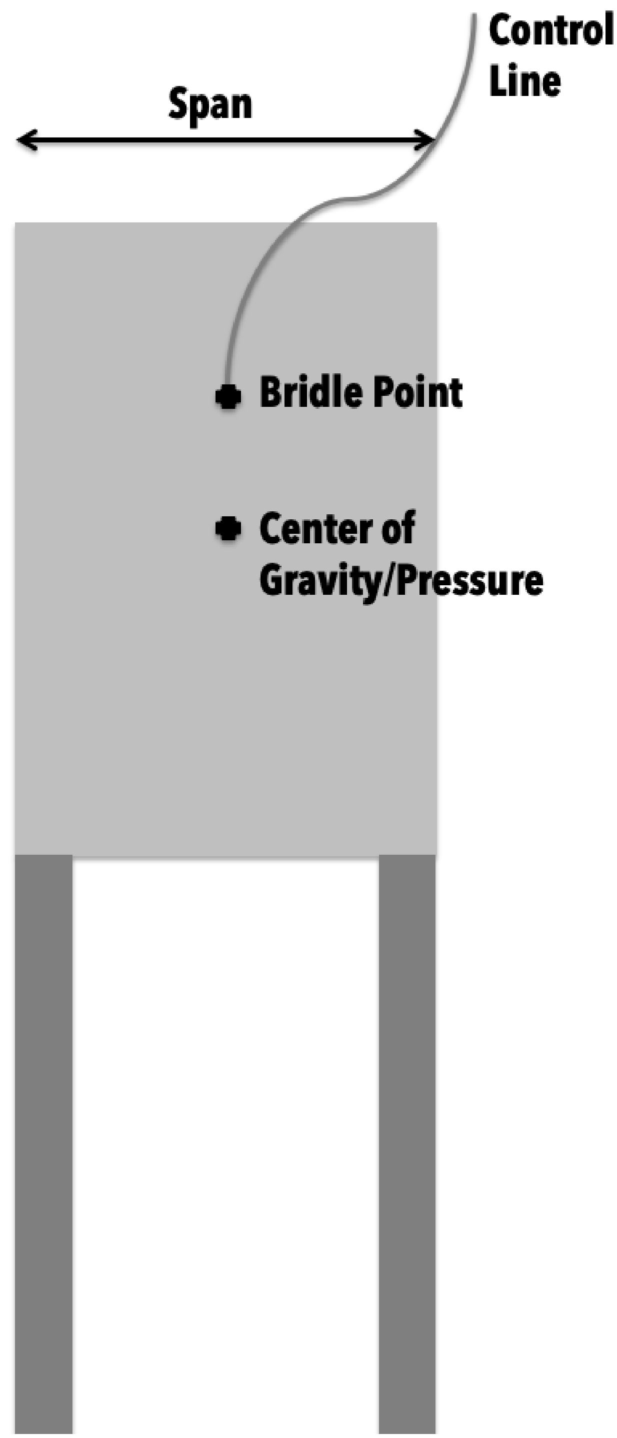
Throughout this activity, students will practice teamwork and communication with each person having an equal voice. After creating and flying their own kite designs and filling in their data sheets, students can discuss together what they saw and how the changes in their designs affected the kite flight. We would also encourage the group to pick out the kite design that was most successful, and discuss why. One student from each group can present the findings to the class. This group work gives the students a chance to brainstorm improvements and further iterations of their designs. The instructor can also emphasize the importance of teamwork and communications in other STEM situations, including NASA mission teams.

Extended Learning

If time, students can craft yet another kite design, the BumbleBee, using the same set of materials (see p. 14).

Mini Kite Diagram





Surface Area
$= 2 \times 3 = 6\ in^2$

Aspect Ratio
$= Span^2 / Surface\ Area$
$= 2^2/6 = .66$

Mini Kite design courtesy of Glenn Davison/American Kite Fliers Association (AKA)

Standard Mini Kite Test

Describe Flight

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What Happens If You Change The Flying Speed Of The Kite?

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Hypothesize What Aspects Of The Kite Contribute To Successful Flight

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Design Challenge

Draw The Kite Design

Describe Design Changes

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Describe How You Think It Will Perform

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Creative Design Mini Kite Test

Describe Flight

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How Did It Compare With The Standard? How Was It Better/Worse?

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Within Your Group, Describe Why The Most Successful Kite Design Flew Well

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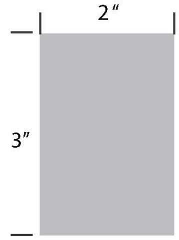
Notes:

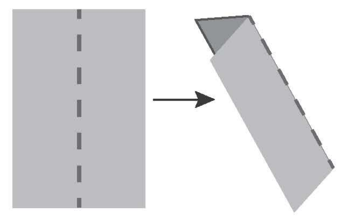
Mini Kite Diagram

Make a Mini Kite Instructions

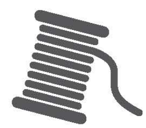
1. CUT A 2" X 3" PIECE OF TISSUE PAPER FOR THE KITE BODY.



2. FOLD THE KITE BODY IN HALF LENGTHWISE.



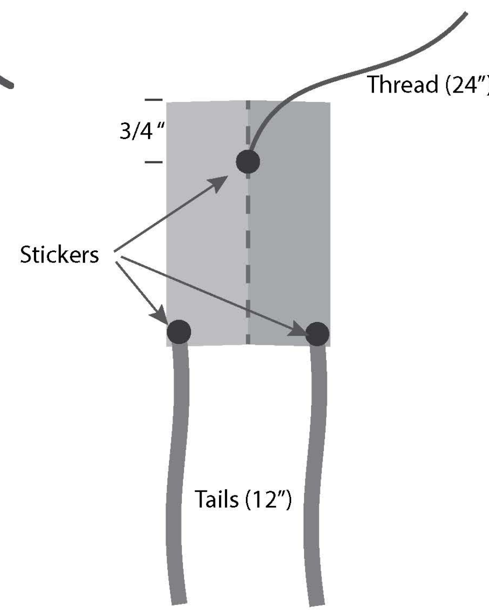
3. CUT 24" OF THREAD.



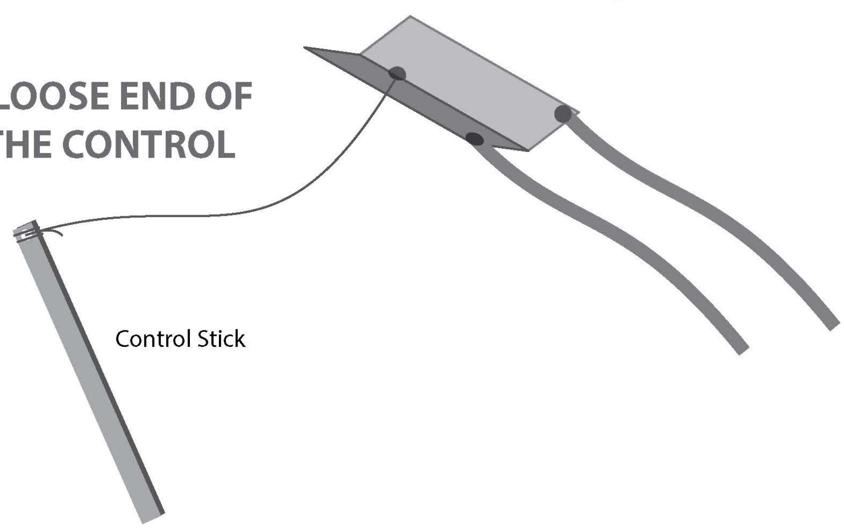
4. MEASURE 3/4" FROM THE TOP OF THE KITE ALONG THE FOLD AND DRAW A DOT.

   USE A STICKER TO ATTACH THE THREAD HERE.

5. USE STICKERS (OR TAPE) TO ATTACH THE TWO 12" TAILS TO THE KITE BODY AT THE BOTTOM CORNERS.



6. TIE OR TAPE THE LOOSE END OF THE THREAD TO THE CONTROL STICK .

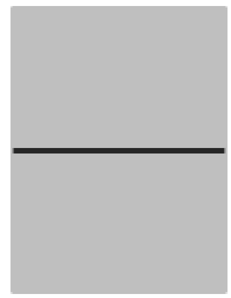


Mini Kite design courtesy of Glenn Davison/American Kite Fliers Association (AKA)

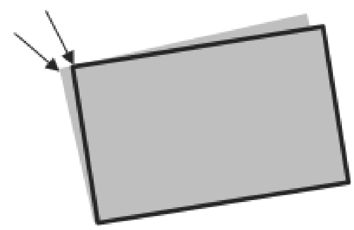
Mini Kite Diagram

Bonus Design: Bumblebee Kite

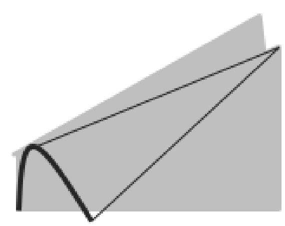
1. CUT OUT 3x4" TISSUE PAPER
2. FOLD PAPER IN HALF LENGTHWISE



3. BEND TWO FRONT CORNERS TOWARDS FOLD (DO NOT ACTUALLY FOLD)



4. TAPE THE BOWED CORNERS ABOUT ½" FROM KITE FRONT



5. CUT 24" OF THREAD

6. TAPE THREAD TO THE ATTACHMENT POINT FROM STEP 4