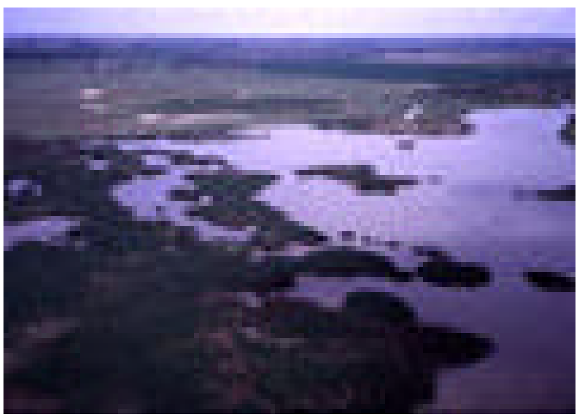
You Decide Scenario

NASA is interested in taking aerial photos in a stealth manner, without risking human life. Because loud aircraft would cause problems, rotorcraft, airplanes, and other motorized vehicles are out of the question! The best non-manned vehicle that can take aerial photos is a kite! It is your mission to develop a kite that can:

- Hold a camera that can take pictures at low altitude
- Fly in non-inclement weather
- Be flown in wind conditions ranging from 6 to 20 miles per hour
- Be constructed using only supplies supplied by your teacher or on the list in the resource packet.

In this project, you will:

- Research what is already known about kite history and aerodynamics
- Design a kite and create a blueprint of it
- Construct the kite
- Test the kite for balance and a trait affecting lift and drag
- Quantify aerodynamic force vectors
- Determine height of kites using trigonometry



Follow the "Steps to Completion" (see the resource list) to help get you started!

At left is an example of an aerial photo taken with a kite by NASA researchers.

Kites with Cameras

In this project, one goal is to take pictures at low altitude with a camera. How big are the cameras and how are they controlled? Although some specialized cameras exist, most people just use standard cameras. These cameras are fitted with special mechanisms for taking photos. You can use any of these mechanisms - just be sure you understand how they work and leave adequate room for them, on your kite or its bridle. You will need to estimate the weight of the camera and associated rig, so you can include this weight in your testing and / or flight of your kite.

At right, a picture of the Brownie Box rig described at the NASA link below (#5).

The following are web sites to explore, to better understand what a rig and camera will look like, and where to put it on your kite or its bridle. When you click on these sites, you may be exiting the NASA web site. These sites are not under NASA control, and NASA is not responsible for the information or links you may find there. NASA is providing these links only as a convenience. The presence of these links on any NASA web site is not intended to imply NASA endorsement of that site, but to provide a convenient link to relevant sites which are managed by other organizations, companies, or individuals.

1. Charles Benton has a very complete site containing information on photography, rigs, and cameras: http://www.arch.ced.berkeley.edu/kap/equip/equip.html

He also has links to some of his friends' sites including:

Bill Nelson: http://www.arch.ced.berkeley.edu/kap/equip/ice.html
Aaron Fulton: http://www.fulton.btinternet.co.uk/kap.htm
Simon Harboard: http://www.arch.ced.berkeley.edu/kap/others/shrig.html
Bob Pebly: http://www.arch.ced.berkeley.edu/kap/others/pebly.html
Jan van der Elsen: http://www.arch.ced.berkeley.edu/kap/others/vdelsen1.html
Wolfgang Bieck: http://www.arch.ced.berkeley.edu/kap/others/wolfgang.html

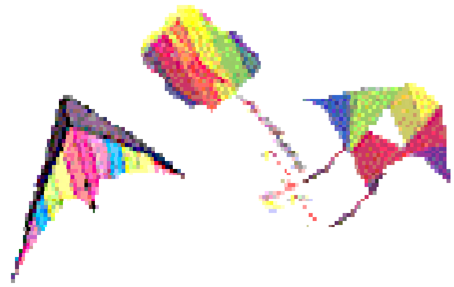
2. Another kite and camera setup with a photo of both in flight: http://www.geospectra.net/kite/equip/kap-rig.htm

3. A link about the use of a disposable camera with timers / radio control: www.rcarchive.com/kite/

4. Detail on the Picavet Suspension Cradle: http://www.faxmentis.nsw.edu.au/ picavet2.html

5. NASA resource and details on building a Brownie Box for a disposable camera: : http://wwwedu.ssc.nasa.gov/kap/kap.htm

Refine Your Kite Design



At right are several popular kite designs including (from left to right) delta, box, and delta-box.

Some cool sites to help in your development of your design are below. When you click on these sites, you may be exiting the NASA web site. These sites are not under NASA control, and NASA is not responsible for the information or links you may find there. NASA is providing these links only as a convenience. The presence of these links on any NASA web site is not intended to imply NASA endorsement of that site, but to provide a convenient link to relevant sites which are managed by other organizations, companies, or individuals.

1. Kite Plans on the Web (note: some links are no longer working and many kites (especially cellular ones) are very complex): http://www.kites.org/tmr/planlink.htm
2. American Kitefliers Association kite plans: http://www.aka.kite.org/kiteplans.html
3. See web quest sites as well, copied below as you saw it during the quest!
4. KiteModeler download *: http://www.grc.nasa.gov/WWW/K-12/airplane/kiteprog.html
*Use only if you have extra time!

Web Quest Resources:
1. Kite Museum: Stabilizing Principles of Flight (yes, it is incomplete): http://www.win.tue.nl/~pp/kites/fak/science/stabilizing.principles.html
2. History and basic info on kites: http://www.grc.nasa.gov/WWW/K-12/airplane/kite1.html
3. Kite history, designs, aerodynamics (see science section under teachers) from National Kite Month's web site: http://www.NationalKiteMonth.org/
4. Aerodynamic forces on a kite: http://www.grc.nasa.gov/WWW/K-12/airplane/kiteaero.html
5. Bridal point geometry: http://www.grc.nasa.gov/WWW/K-12/airplane/kitebrid.html
6. The Kite Zoo (plans and information on the number of lines and kite use): http://www.kites.org/zoo/
7. How to fly different kites: http://www.gombergkites.com/how.html
8. Kite terminology index: http://www.win.tue.nl/~pp/kites/terminology/kiteterm.html#aspectratio
9. A very detailed and well written response to questions about aspect ratio: http://www.kites.tug.com/Building/msg00120.html
10. Aeronautics in the context of airplanes and other flying things explained. Includes Bernoulli's Principle: http://quest.arc.nasa.gov/aero/virtual/demo/main/maeronautics.html
11. Geocities kite sites: http://www.geocities.com/Colosseum/4569/
12. Plans, pictures, and general information: http://enterprise.sct.gu.edu.au/~anthony/kites/
13. Kite history, plans, and general information: http://www.total.net/~kite/index.html

Kite Construction Materials List

The resources listed below will suffice for very large kites. Smaller kites can be made, in which case less materials would be needed. In this design, pieces are taped together. Traditional sewing of seams would also work, though it is more time consuming.
Craft knives and the hand saw should be used with caution; adults should supervise or manage these tools.

Supplies:

- Balsa Wood Dowels (4 per group) or Split Bamboo
- Rice Paper, Butcher Paper, Mylar, Plastic Sheeting, Nylon, or Tyvek (3 yards per group)
- Packing Tape and/or nylon tape (1 roll per two groups)
- String (1 roll per two groups) or kite string on handles (2 per group)
- Shock cord for wingtip connection (1-2 yds per group) - optional
- Buttons (several per group) and/or swivels (4 per group) for attaching string to strings, kites, and Scales for easy movement later
- Scissors and craft knives
- Vinyl tubing for attaching dowels together - optional
- Yard sticks, rulers, protractors, and compasses
- Small and large lockable paperclips (for hanging kites during development and clipping parts together before permanent binding
- Nocks for ends of dowels (6 per group) - optional
- Paint brushes, palettes, and paints for decorating kites (consider kite material when choosing)
- Computers for Web Quest and potentially working with digital blueprints and photographs
- Room Fans
- Small hand saw, extra blade(s), & vices (to be used by adult only)
- Digital Camera - optional
- Floppy Disks - optional, if storing Web Quest data, digital photos, or digital blueprint.
- Virtual Skies tutorial for understanding components of flight
- Spring scales measuring in Newtons (several)
- Wind meters (at least one)
- Graph Paper for blueprints
- Ribbon or nylon tail material

People:

Community members, parents, and/or members of local kite clubs and craft organizations to assist in design, testing, and construction.

Supplies can be purchased from the resources listed below. When you click on these links, you may be exiting the NASA web site. These sites are not under NASA control, and NASA is not responsible for the information or links you may find there. NASA is providing these links only as a convenience. The presence of these links on any NASA web site is not intended to imply NASA endorsement of that site, but to provide a convenient link to relevant sites which are managed by other organizations, companies, or individuals.

Into the Wind is a popular kite supply store in Boulder, Colorado. They sell most of the supplies listed above, as well as ready-made kites, books, and videos. Their home page can be found at http://www.intothewind.com
Arbor Scientific is a retailer specializing in tools for education. The following link takes you directly to their Spring Scale listing: http://www.arborsci.com/testdirectory/Measurement/Measurement_Products.asp
The Weather Place has a large range or measurement devices for determining wind speed. The Dwyer Wind Meter, one of the least expensive, non-electrical meters is found at: http://shop.store.yahoo.com/weatherplace/dwyerwinmete1.html

Steps to Build the Kite

1. Make frame by cutting and binding together dowels (or other rods or split bamboo) with string or tubing. The frame should be sturdy and well balanced. You can attach a short bridle now, or after the kite fabric is added.
2. Cut the fabric to be slightly larger than the frame. Decorate the kite fabric. Be sure it is dry before attaching it to the frame.
3. Attach the kite fabric to the frame. Extra fabric can overlap the frame and be adhered to the frame with tape or glue. Glue works well for rice paper or butcher paper. Special glue may work well for plastic or nylon. Nylon tape works well with nylon. Packing tape works well with all materials.
4. Attach the tail(s) to your kite.
5. Attach the bridle (if not already attached) and test the kite again for balance. If the bridle punctures the kite fabric and a tear starts, you can reinforce the fabric with adhesive hole-punch reinforcers or tape. If your kite is unbalanced, is better to reduce weight on the heavier side than add a counter balance on the lighter side.
6. Lengthen the bridal for flying. It is a good idea to use swivels so it is easy to attach and disconnect the bridle to the string as needed. A swivel also comes in handy for flight testing (connect to a spring scale).

Using Vectors to Summarize Direction and Magnitude

Vectors are used for depicting direction and magnitude of motion, force, or other changes. Vectors are displayed on graphs and with numbers.
Vectors are explained with the following three examples, to show you some of the diversity of vector applications, as well as give you ideas of how vectors are related to your kite.

<u>Example 1</u>: A honeybee is travelling from rose to clover. As an entomologist, you are interested in documenting its pollination journey.

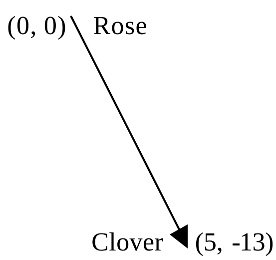
<u>Example 2</u>: A kite is being pulled by the wind along its bridle line at a strong force (you can feel it tugging). You are interested in determining how much lift and drag your kite must have, based on this force.

<u>Example 3</u>: The Coast Guard's gauge for water speed and direction have broken, so they need to determine the water speed and direction, using the known driving speed of the boat and their starting and stopping buoy positions.

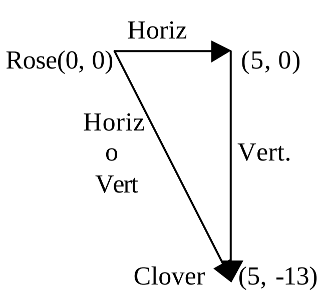
Display on graphs

A vector looks a lot like a line segment, when displayed on a graph. The graphical display of a vector can help someone better understand the direction and magnitude of the vector, otherwise displayed with numbers, below. Often arrows are added to summarize the direction of travel. The starting position can also be labeled (x_1,y_1), and later points (x_2, y_2) and so on.

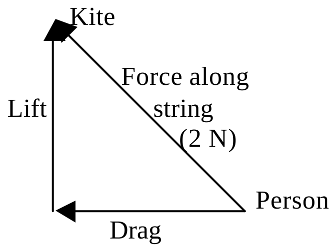
<u>Example 1</u>: The bee starts at the rose and ends at the clover. If the rose is at (0, 0) (staring point or origin), and the clover is at (5, -13) (5 feet to the right and 13 feet down from the rose), the path can be graphed as follows.



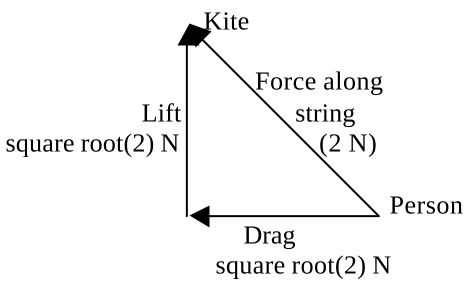
Notice that the journey could be broken down into vertical movement and horizontal movement. This graph is useful for summarizing a vector with numbers. Breaking the journey into the two movements creates a right triangle, which we can label as follows. Thinking about vectors in terms of right triangles is very useful for more advanced vector problems, like those in examples 2 and 3. Note that the vertical and horizontal components connect end to end or arrowhead to arrowhead) to create the diagonal (hypotenuse) vector. "Adding" vectors in this way is very common and is called creating a dot product. In other words, Horiz º Vert = Diag. Notice that NO multiplication is involved in creating a dot product, despite its name. The symbol in the equation above is not a multiplication symbol, but an open dot.



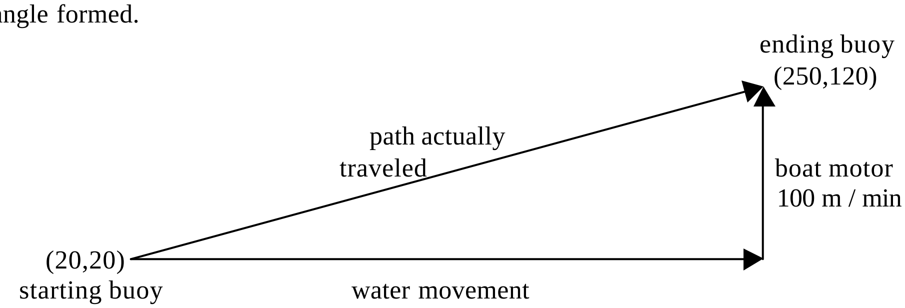
<u>Example 2</u>: A spring scale is attached to the kite's bridle and measures 2 Newtons. You measure the bridle as being 45 degrees relative to the horizon. Lift is vertical to the horizon and pulling upwards, and drag is parallel to the horizon and pulling in the same direction as the wind (away from you). You can plot the vector for force along your string and associated lift and drag vectors, as follows.



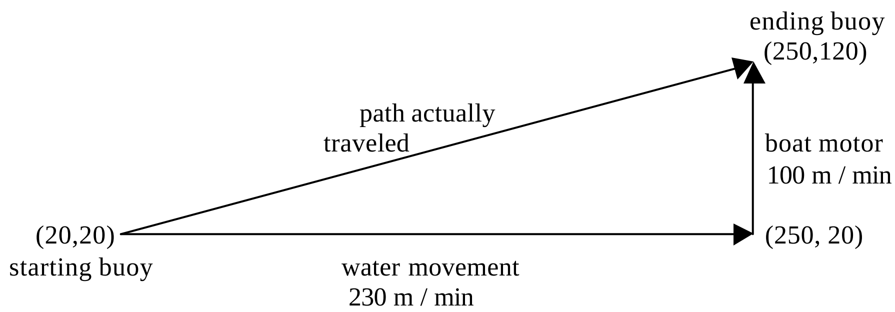
To find the lift and drag vectors, you can recall that a 45-45-90 degree right triangle has side lengths of x and a hypotenuse of x times the square root of 2. A 45-45-90 degree triangle is also isosceles, so the side lengths squared should add to make the hypotenuse length squared, using Pythagorean Theorem: $x^2 + x^2 = 2^2$ Newtons^2. Trigonometry could also be used to solve this.
Now the graph can be labeled completely.



<u>Example 3</u>: The buoy the Coast Guard starts at is at (20,20) (20 meters up from and to the right of the dock). The buoy the boat ends at is at (250, 120) (250 meters to the right of and 120 meters up from the dock). The boat steers directly up (no right or left steering) and moves at 100 meters per minute for one minute. Two vectors can be plotted here - actual movement of the boat (connect the dots between the buoys) and the upwards movement of the boat that is intended. Remember that the Coast Guard wants to know how fast the water is moving and in what direction, so that will be the third vector in the right triangle formed.



To find the third vector, simple coordinate geometry is the easiest method to apply. When it is solved for, the completed graph looks like the one below. Notice that the units chosen are in meters per minute, as the speed of the water is what is desired. (It should be noted that water only moves in the horizontal vector, because the boat's motor took care of the entire vertical vector. A more complex problem would be if the boat's motor did not cover the entire vertical distance.)



Display with Numbers

There are two kinds of number displays.

?? Direction

Direction is often thought of as N, S, E, or W. Direction can become more specific by combining directions (e.g. NW, SE), or providing angle measurements. Vectors are a very precise way of providing direction, in terms of a horizontal and vertical component. How nice, that we have pictures of these components, above! Direction is shown as a coordinate pair, (x, y), further described below.

direction = (change in horizontal movement, change in vertical movement)

Because it is important to distinguish between up-right movement and down-left movement, when determining change in movement, always use the following equation:

change in movement = ending position - starting position

?? Magnitude (Distance)

Magnitude or distance can be determined with the Pythagorean Theorem, trigonometry, special triangle rules, and the distance formula, as you saw in the examples above. The distance formula is:

D = square root ($(x_2 - x_1)^2 + (y_2 - y_1)^2$)

The distance formula is simply another form of the Pythagorean Theorem, where D can be thought of as the hypotenuse, and (x_2-x_1) and (y_2-y_1) are the lengths of the horizontal and vertical sides of the right triangle.

As (x_2-x_1) and (y_2-y_1) indicate the changes in horizontal and vertical movement, if the direction of the vector is already known, the magnitude of the vector can be calculated easily with the following equation:

D = square root(change in horizontal movement ^{2} + change in vertical movement^2)

<u>Example 1</u>: I used the graph to help me solve. Additionally, work is shown if the graph had not been produced.

Direction = (5-0, -13-0)
= (5, -13)
Magnitude = square root (5^2 + -13^2)
= square root (25 + 169)
= square root (194)

<u>Example 2</u>: Three vectors are described. They will be labeled as V_x (horizontal vector), V_y (vertical vector), and V_{xoy} (diagonal vector or dot product).

V_x

Direction = ((square root(2)) - 0, 0)
= ((square root(2)), 0)
Magnitude = square root ((square root(2))^2 + 0^2)
= square root(2) Newtons

V_y

Direction = (0, (square root (2)) - 0)
= (0, (square root (2)))
Magnitude = square root (0^2 + (square root(2))^2)
= square root(2) Newtons

V_{xoy}

Direction = ((square root(2)) - 0, (square root (2)) - 0)
= ((square root(2)), (square root (2)))

Magnitude = square root ((square root(2))^2 + (square root(2))^2)
= 2 Newtons

<u>Example 3</u>: Three vectors are also described here, labeled as in example 2.

V_x

Direction = (250 - 20, 0)
= (230, 0)

Magnitude = square root ($230^2 + 0^2$)
= square root (230^2)
= 230 meters per minute

V_y

Direction = (0, 120-20)
= (0, 100)

Magnitude = square root (100^2)
= 100 meters per minute

V_{xoy}

Direction = (250-20, 120-20)
= (230, 100)

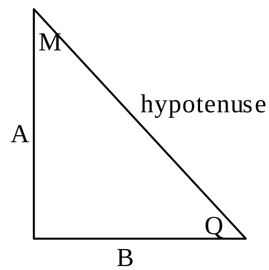
Magnitude = square root ($230^2 + 100^2$)
= square root (52900 + 10000)
= square root (62900)
= 10 (square root(629)) meters per minute

Using Trigonometry to Determine Distances and Angles

Trigonometry involves ratios of numbers. The numbers from basic trigonometry represent sides of right triangles. There are three ratios to memorize with the term "SOH-CAH-TOA."

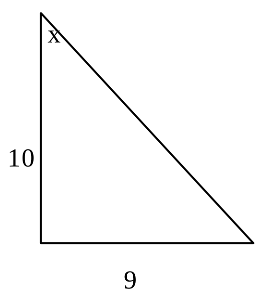
SOH represents S = O / H or sine (angle) = opposite / hypotenuse
CAH represents C = A / H or cosine (angle) = adjacent / hypotenuse
TOA represents T = O / A or tangent (angle) = opposite / adjacent

Opposite and adjacent vary, depending upon the reference angle chosen. For instance, in the triangle below, side A is adjacent (touching) angle M, and side B is opposite (not touching) angle M. Side A is opposite angle Q, while side B is adjacent to it.



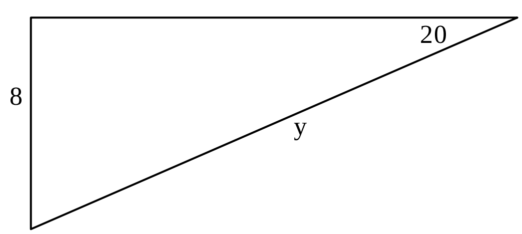
To solve any trigonometry problem, you should:
(1) draw a right triangle and label all known parts.
(2) determine which ratio is appropriate for known side lengths
(3) write an equation with one variable
(4) solve the equation with the help of a chart or calculator
(5) check to be sure your answer makes sense

Example 1:



If you wanted to solve for angle x, above, and only want to use the side lengths provided, you would determine that the tangent ratio is best for this problem, because only adjacent (10) and opposite (9) values are given. tan (x) = 9/10 or tan(x) = 0.9.
With a chart or a calculator's $\tan^{-1}$ button, I find that the angle that satisfies the equation is approximately 42 degrees. This makes sense, as the triangle is almost isosceles, which would reveal a 45-degree angle.

Example 2:

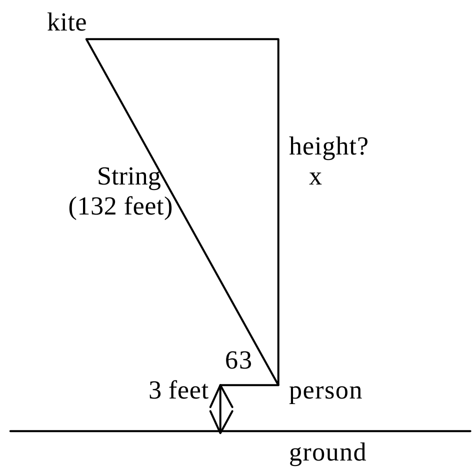


In example 2, hypotenuse and opposite sides are given, so sine will be used. sin (20) = 8 / y
Using a chart or the sin button on a calculator, sin(20) is found to be 0.3420. That makes the original equation the same as 0.3420 = 8 / y or 0.3420y = 8. Therefore, y equals about 23.3918. This answer seems reasonable, as the hypotenuse must be over twice as long as the shortest leg (8). It would be 16 if the angle was 60 (30-60-90 Theorem).

Example 3: When you fly your kite, you will be able to physically measure the angle at which the kite is flying and the length of the string, but will not be able to measure its height without trigonometry.

Here is an example of what you may have to work with:
You are flying your kite at a 63-degree angle of elevation (relative to the horizon), and have 132 feet of kite string out. How high is your kite above he ground, if you are holding the string 4 feet off of the ground?

To solve, first draw the picture:



90- 63 = 27, which is the angle inside the triangle, where the person is standing. This will be the angle we will use in our equation. Hypotenuse and adjacent are to be used, so we will be working with cosine.
cos (27) = x / 132 or 0.8910 = x / 132 or x = 117.6120. This makes sense, as the height should be less than the hypotenuse and a little more than square root (3) / 2 times the hypotenuse (the height for a 30-60-90 triangle).

KiteModeler: Using NASA Online Tool to Virtually Build and Test Kite Design

KiteModeler was developed as NASA Glenn Research Center. It is a very easy-to-use Java applet that can help you check the dimensions you are planning for, in the kite design process.

Downloading and Running Kite Modeler

- ?? Go to http://www.grc.nasa.gov/WWW/K-12/airplane/kiteprog.html
- ?? Scroll to the bottom of the page and press the Download button. All of the information about graphics and variables in the software will occur on the web page when you run the software, so DO NOT PRINT IT.
- ?? When the program is downloaded, a zip-compressed file will be placed on your computer or disk (wherever you specify, unless a default placement has been chosen). If you cannot find the zip file, you can use the find function on your computer to locate it. It should be saved as KiteModeler.zip.
- ?? Decompress the program and save its contents (21 class files, 2 html files, and 1 Java file).
- ?? Run the applet by dragging the KiteModeler.html file into a browser window like Internet Explorer or Netscape. It should load after a few seconds and be fully functional.

Using KiteModeler

The program is simple and extremely easy to use! Follow these steps to build your kite and see how stable it is, as well as estimate vectors.

6. Press the shape button and pick the type of shape you would like from the menu to the right of it.
7. Press the material button and choose the four kinds of materials you will use. The first material is for the kite surface. The second material is for the rods that make up the kite's frame. The third material is for the tail, and the last material is for the line. You will notice that as you pick materials, different weights are inputted, which will help calculate aspects of kite aerodynamics later. Pick the closest item if you are unsure about the material. Weights are approximate.
8. Press the shape button and pick the kite's different dimensions. Use the four left-right scrollbars to choose the two heights and widths. The view of your kite should change as you manipulate the scrollbars. You will likely return to these dimensions, to alter your kite. Notice that changing these dimensions changes the data in the black boxes in the top right quadrant of the screen. You may notice that as you change to some values, a red and yellow warning message appears in the view portion of your screen, to indicate that the design or trim of the kite is not stable. You may notice that this happens when Torque becomes negative, Lift is far less than Drag, or Weight is too high. If your kite size is bigger than the view window, you can use the vertical yellow scrollbar on the left of the viewing box, to modify your perspective to a larger or smaller one.
9. Press the Trim button to alter how the bridle line is connected to the kite. You will probably want to view the kite from the side view. To change this, pick the option Select View at the top of the view box, and press the Side option. If you are unclear about the different variables involved in trim, scroll down the applet screen to read about them. You can set the trim angle by pressing the Set Trim Angle option on the menu at the center right of the page. Similarly, the computer can calculate the trim angle with the other menu option.
10. See how your kite would be flying in a field by changing the view to a field view (Use the Select View and Field options at the top of the viewing box). X and Y vectors are labeled, so you could potentially use this picture to help you determine the force along your string, using the lift and drag data from the black boxes in the applet.,
11. Once you are happy with your results, record your data. Notice that data can be recorded as Metric or English units. You can change between these by pressing Metric at the top of the viewing box.

Please remember that the KiteModeler Software is not perfect, but can be used as an indicator for poor or excellent design choices!

Develop a Hands-on Kite Test

1.Think of <u>one feature</u> that could be changed and how its alteration will affect kite lift or drag. You might consider the concepts from the web quest or even something that isn't well researched. Be sure it can be tested easily with a fan & spring scale set up shown below, potentially combined other classroom materials. If you are having trouble thinking of ideas or are ready to predict what you will measure, you can play with this Kite modeling software, called KiteModeler: http://www.grc.nasa.gov/WWW/K-12/airplane/kiteprog.html

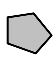
2. Some things to know about testing:

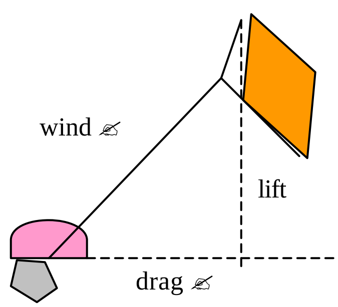
7. Testing should focus on the change in lift and / or drag as a result of changes in the kite.
8. Balance and center of gravity can also be observed for, during testing.
9. Testing may be conducted with a miniaturized model of the kite, or a duplicate of the kite to be flown.
10. Testing should be repeated at least 3 times in order to assure validity and reliability of data.
11. Measurement of forces will be conducted in identical ways on kite flying day.

3. Fan & spring scale set up:

12. The fan we will use produces wind speeds up to about 10 miles per hour. Wind speed can be measured with a wind meter. The fan would be placed to the left of the image below, to produce wind.
13. The spring scale measures force in Newtons, or kg*m/s^2, in a range of 0.05 to 50 Newtons. For small or medium-sized kites, a 250 g / 2.5 N scale is best. Larger kites may require 1000g / 10 N or 5000 g /50 N scales, particularly when flying in natural wind.
14. A protractor set parallel to the floor will be used to measure the attach angle of the bridle.
15. A scale can be used to measure weight (mass* gravitational force) of the kite, in grams, which must then be converted to Newtons using the gravitational constant (9.8 m/s^2) and a conversion factor (1000 g = 1 kg).
16. A hand-held wind meter will measure wind speed in miles per hour.
17. Trigonometry will be used to determine the lift and drag vectors, using the angle of attack and force vector along the bridle.

Protractor 
(to measure angle of attack)

Spring scale 
(to measure force along bridle)



Start your rough draft of the test, below:

The ONE FEATURE you will test for is:

____

What is your hypothesis?

____

Briefly describe your experiment in the space below and on the back of this sheet. Use sketches to help you explain.

Aeronautical Features to Consider

If you have trouble designing your kite test, consider the following.

How do lift and drag vary with changes in kite design features like:

(1) Aspect Ratio
(2) Cant or Bowing
(3) Angle of Bridle relative to kite
(4) Lengths of Different Parts of the Bridle
(5) Size of Fins
(6) Length and Weight of Tail
(7) Placement of Tail
(8) Venting
(9) Width of Kite (or changes in one of the widths)
(10) Height of Kite (or changes in one of the heights)

Or think of your own!

You will be doing a web quest about some main issues in the aerodynamics of kites.
(11) Before starting, write what you think you already know about each of the following topics.
(12) Then conduct the web quest and add to / change your initial ideas as you go.
(13) Tip #1: Write in your own words or put quotations around direct quotes. You may want to use some of these ideas later, so you need to know which are your words versus the words of others.
(14) Tip #2: Use the FIND function in your network browser to find keywords on any page. This will speed up your scanning for information!
(15) Tip #3: Don't spend too much time on one question – if you can't find the answer, move on- you may find it later!

1. Aerodynamics: In what direction do lift, drag, and weight occur? How could these be measured?
2. Newton's Third Law states that for every action that is an equal and opposite reaction. How is this related to kite flying? (Hint: How is it related to #1?)
3. What is cant or bowing? How does cant help create lift and stability? Is there a limit to its power (too much or too little cant)?
4. Some kites have one string, and some have more. What are advantages to having more?
5. Some kites fly better at different wind speeds. Describe the speeds and which kites work best with them. Also describe the feature of each kite that makes it best suited for that speed.
6. What is venting? What purpose does it serve?
7. Almost all kites have tails. What functions do they serve? Would it be better to have a long or short tail for a kite at high altitude?
8. What is a rudder and where would you find it on a kite? How is it controlled? What purpose does it serve?
9. Most people think kites are just for fun. However, historically, kites have had more functional purposes. What are these?
10. Bernoulli's Principle is very important for flier design. Describe the principle and how it will apply to your kite.
11. Symmetry is very important in almost all designs, and an example of this is the formation of a dihedral. What is a dihedral? If your kite is asymmetrical, what is likely to occur?
12. What is pitch and roll? What parts of the kite influence pitch and roll?
13. What is the bridle point? What trigonometric equation is used to find it?
14. Aspect ratio is an important concept to consider when developing any flier. What is it? Describe how aspect ratio influences lift and drag. Which is better: a kite with a high or low aspect ratio?
15. If the wind is coming from the East, in which direction do you run/walk, to get your kite to take flight?
16. Experimentation with kites led several scientists to some major discoveries / developments in many fields. List as many of them as you can:
17. Do you have any other questions about kites? (optional)

Here are sites to start your quest. Split things up in your group and remember to use your FIND function in your browser to speed up scanning! When you click on these sites, you may be exiting the NASA web site. These sites are not under NASA control, and NASA is not responsible for the information or links you may find there. NASA is providing these links only as a convenience. The presence of these links on any NASA web site is not intended to imply NASA endorsement of that site, but to provide a convenient link to relevant sites which are managed by other organizations, companies, or individuals.

1. Kite Museum: Stabilizing Principles of Flight (yes, it is incomplete): http://www.win.tue.nl/~pp/kites/fak/science/stabilizing.principles.html
2. History and basic info on kites: http://www.grc.nasa.gov/WWW/K-12/airplane/kite1.html
3. Kite history, designs, aerodynamics (see science section under teachers) from National Kite Month's web site: http://www.NationalKiteMonth.org/
4. Aerodynamic forces on a kite: http://www.grc.nasa.gov/WWW/K-12/airplane/kiteaero.html
5. Bridal point geometry: http://www.grc.nasa.gov/WWW/K-12/airplane/kitebrid.html
6. The Kite Zoo (plans and information on the number of lines and kite use): http://www.kites.org/zoo/
7. How to fly different kites: http://www.gombergkites.com/how.html
8. Kite terminology index: http://www.win.tue.nl/~pp/kites/terminology/kiteterm.html#aspectratio

9. A very detailed and well written response to questions about aspect ratio: http://www.kites.tug.com/Building/msg00120.html
10. Aeronautics in the context of airplanes and other flying things explained. Includes Bernoulli's Principle: http://quest.arc.nasa.gov/aero/virtual/demo/main/maeronautics.html
11. Geocities kite sites: http://www.geocities.com/Colosseum/4569/
12. Plans, pictures, and general information: http://enterprise.sct.gu.edu.au/~anthony/kites/
13. Kite history, plans, and general information: http://www.total.net/~kite/index.html

Teacher's Key: Web Quest

Web Quest as a tool in Development

You will be doing a web quest about some main issues concerning the aerodynamics of kites.

- ?? Before starting, write what you think you already know about each of the following topics.
- ?? Then conduct the web quest and add to / change your initial ideas as you go.
- ?? Tip #1: Write in your own words or put quotations around direct quotes. You may want to use some of these ideas later, so you need to know which are your words and which are not.
- ?? Tip #2: Use the FIND function in your network browser to find keywords on any page. This will speed up your scanning for information!
- ?? Tip #3: Don't spend too much time on one question – if you can't find the answer, move on- you may find it later!

- ?? Aerodynamics: In what direction do lift, drag, and weight occur? How could these be measured?

Lift = perpendicular to the wind direction, opposite of gravity force (weight)

Drag = Perpendicular to lift, parallel to and in the same direction as wind

Measurement strategies may vary, though some students will think of using a scale.

- ?? Newton's Third Law states that for every action that is an equal and opposite reaction. How is this related to kite flying? (Hint: How is it related to #1?)

Lift is the force of air pushing on the kite as the kite pushes down (with the help of gravity and weight).

- ?? What is cant or bowing? How does cant help create lift and stability? Is there a limit to its power (too much or too little cant)?

Bowing "can be a smooth curve or an angle," often "at the center of the kite." It helps the kite catch the wind, like a parachute does. It can increase lift, especially if the kite is like a cambered wing (see below), due to Bernoulli's Principle. Having too much cant might trap wind and create too much drag, or provide too much weight. Having too little will cause kite to act as if there is none, so the pressure difference between the top and bottom of the kite is not very different.

- ?? Some kites have one string, and some have more. What are advantages to having more?

More strings mean more maneuverability that can help the kite do tricks and move more quickly.

- ?? Some kites fly better at different wind speeds. Describe the speeds and which kites work best with them. Also describe the feature of each kite that makes it best suited for that speed.

"Deltas, diamonds, and dragon kites fly well in light to medium winds (approximately 6-15 mph), while Box Kites and stickless Parafoil kites fly better when the winds get a little stronger (approximately 8-25 mph)." Box and parafoil kites have depth to them or several layers of sails, so wind needs to be strong enough to work between these layers and still provide significant pressure differences. The low-wind kites have a single layer, so require less wind.

- ?? What is venting? What purpose does it serve?

Venting involves cutting slits or holes for air to pass through. This can provide stability for the kite.

- ?? Almost all kites have tails. What functions do they serve? Would it be better to have a long or short tail for a kite at high altitude?

Tails provide flight-axis stability to keep the kite from spinning about the axis (rolling) or darting laterally. It also provides downward weight to prevent too much pitch movement. (Aesthetics may also be mentioned.)

Long tails at better at high altitude; more force is required to stabilize the kite, and a long tail can produce more drag than a short tail.

- ?? What is a rudder and where would you find it on a kite? How is it controlled? What purpose does it serve?

"A rudder is anything that is oriented perpendicular to the plane of the main sail of the kite." It can be controlled by the wind (if attached in a stable manner to the main sail / kite frame or with a tail to keep it in place), or by a string the kite flier can control. If controlled with string, it can be used for steering.

- ?? Most people think kites are just for fun. However, historically kites have had more functional purposes. What are these?

"Kites are used as a fishing aid in the Solomon Islands. Kites are used by the Koreans to announce the birth of a child. Kites were used by the Chinese during battles. " Kites carried people who provided air surveillance, as well as messages received by airplanes or people living at high altitudes. Kites were used to improve velocity in buggy or boat travel, and marked locations of people lost at sea. Kites have also been used "to measure, and conduct scientific experiments, for target practice, to fight and compete, to entertain, and a endless list of other utilizations," including construction of buildings,

- ?? Bemoulli's Principle is very important for flier design. Describe the principle and how it will apply to your kite.

As air passes over propellers, cambered wings, or even a cambered kite sail, the air above the sail moves over more area, so its pressure decreases. Conversely, the air at the bottom has a higher pressure. This pressure difference results in lift.

One interesting thing for students to test is comparative lift between a kite that is like a cambered wing, made up of a bowed sheet and a flat sheet, such that there are two sheets enclosing empty space, versus a kite with a single bowed sheet.

- ?? Symmetry is very important in almost all designs, and an example of this is the formation of a dihedral. What is a dihedral? If your kite is asymmetrical, what is likely to occur?

The dihedral, or angle formed where two sides of the kite come together, must be balanced or symmetrical, so that wind presses equally on both sides. If it is not, the wind presses unequally on the sides and it will roll. Asymmetry in other parts will cause the kite to be unstable.

- ?? What is pitch and roll? What parts of the kite influence pitch and roll?

Pitch is rotation about the lateral axis (movement of top tip downward).
Roll is rotation about the longitudinal (vertical) axis (left tip goes to right).
If the kite is not balanced on right and left wing, rolling may occur. If it is not properly balanced with bridal, top, and bottom, the kite may want to pitch.

- ?? What is the bridle point? What trigonometric equation is used to find it?

The bridal point is the point at which the string attached to the kite attaches to the bridal (main flight string). The equation to determine where it should be (x, y) is:

$X = K\cos A$; $y = K\sin A$

$\cos A = (K^2 + H^2 - (B-K)^2)/2KH$

K is the bottom string length attached from bridal point to the kite.
B is the top string length attached from the bridal point to the kite.
H is the height of the kite.

- ?? Aspect ratio is an important concept to consider when developing any flier. What is it? Describe how aspect ratio influences lift and drag. Which is better: a kite with a high or low aspect ratio?

Aspect ratio = span / chord for a flat kite OR (span * span)/area for more complex kites.
The aspect ratio is directly related to the ratio between lift and drag. Thus, the higher the aspect ratio, the higher the lift during flight. Some people, however, state that it is more difficult for a high aspect ratio kite to take off than a low one.

- ?? If the wind is coming from the East, in which direction do you run/walk, to get your kite to take flight?

Your back should be to the wind, so your kite will take off into the wind.

- ?? Experimentation with kites led several scientists to some major discoveries / developments in many fields. List as many of them as you can:

Answers will vary.

12. Study of variations of temperature and altitude
13. Research electricity (Ben Franklin & Alexander McAdie)
14. Aerial Photography
15. Development of the Airplane and Gliders (Alexander Graham Bell and Wright Brothers)
16. Bridge construction – kites assisted in laying initial spanning lines (Homan Walsh)
17. Improvements in target practice for moving aerial targets (like airplanes in WWII)(Paul Garber)
18. Transport of messages between ships and aircraft (WWII development)(Paul Garber)

- ?? Do you have any other questions about kites? (optional)

Here are sites to start your quest. Remember to use your FIND function in your browser to speed up scanning!:

1. Kite Museum: Stabilizing Principles of Flight (yes, it is incomplete): http://www.win.tue.nl/~pp/kites/fak/science/stabilizing.principles.html
2. History and basic info on kites: http://www.grc.nasa.gov/WWW/K-12/airplane/kite1.html
3. Kite history, designs, aerodynamics (see science section under teachers) from National Kite Month's web site: http://www.NationalKiteMonth.org/
4. Aerodynamic forces on a kite: http://www.grc.nasa.gov/WWW/K-12/airplane/kiteaero.html
5. Bridal point geometry: http://www.grc.nasa.gov/WWW/K-12/airplane/kitebrid.html
6. The Kite Zoo (plans and information on the number of lines and kite use): http://www.kites.org/zoo/
7. How to fly different kites: http://www.gombergkites.com/how.html
8. Kite terminology index: http://www.win.tue.nl/~pp/kites/terminology/kiteterm.html#aspectratio
9. A very detailed and well written response to questions about aspect ratio: http://www.kites.tug.com/Building/msg00120.html
10. Aeronautics in the context of airplanes and other flying things explained. Includes Bernoulli's Principle: http://quest.arc.nasa.gov/aero/virtual/demo/main/maeronautics.html
11. Geocities kite sites: http://www.geocities.com/Colosseum/4569/
12. Plans, pictures, and general information: http://enterprise.sct.gu.edu.au/~anthony/kites/
13. Kite history, plans, and general information: http://www.total.net/~kite/index.html

Steps to Completion

18. Brainstorm Kite Design Ideas. Make sketches and write narratives about special features and how they help the kite fly.
19. Web Quest. (see resource list)
20. Blueprint your kite. Revisit your brainstorm ideas, and refine them, using knowledge from your Web Quest and the Design Resource links (see resource list). Include a detailed drawing that is to scale and shows important measurements and angles. Also include a narrative description of special features.
21. Experiment with KiteModeler to determine if your blueprint is stable and estimate aerodynamic vectors (see resource list)
22. Design a Kite Test. (see resource list)
23. Build the kite. Make 2 models (one can be miniaturized) or one that is easy to change, depending on test results. The Construction Resource List has some recommended supplies (see resource list).
24. Test your kite and refine it accordingly. Don't forget to also refine your blueprints!

Fly your kite! Measure the lift and drag vectors, as well as height, using trigonometry (see resource list)!

Behavioral Rubric

		Points: Earned	Possible
Student appears on task at all times			
	Student needs to be reminded to return to tasks		-1
	Student uses class time for work other than math		-1
	Student appears aware of daily tasks and homework		1
Student is prepared with appropriate supplies and background material			1
Works effectively with group, but also knows when to work independently on individual tasks			1
Student disrupts other students or group work			-1
Student can show teacher progress upon request			1
Student uses contract to check progress and make goals			1
TOTAL:			5

Project Rubric

		Points: Earned	Possible
Kite Model			
	Scale Transformation		

	Kite to scale, related to blueprint		1
	Artwork to scale, related to paper copy in report		1
	Neat and clear		1
	Aesthetically pleasing (design, color)		1
Supplies			
	Parameters not adhered to for supply amount and type		minus ?
Bridal point appropriate			
	Calculations clear and appropriate		2
	Figure		1
	Appropriate based on kite balance		1
Symmetrical			
	Kite well balanced		1
Ready on time			
	Completely prepared for flight on due date (+ 10 minutes)		3
	Guide strings attached and usable		1
Aerodynamically sound			
	Constructed appropriately to be lightweight and aerodynamic		1
	Structurally altered according to findings in kite test		2

Stable Assembly and Design		1

Report

Blueprint with measurements

all measurements shown (hatch marks for duplicates)		2
all angles		2
scale / legend		1

Blueprint with supplies

Shading appropriate		1
Legend		1
(Optional) Cartoon for assembly helps understand kite design		0

Blueprint with special features

Special Features numbered		1
Features listed		1
Rough draft: List and explanation of features, purposes		1

Narrative explanation of features

All features included (with number) in bold		1
Aerodynamic purpose explained		3
Aesthetic purpose explained		2
Clear and well written		1

		Grammar and spelling			1
Blueprint with special shapes					
	Shapes numbered				1
	List / legend				1
	Explanation with brief proof/ definition				1 x 12
	12 shapes listed				~
Scale Transformation					
	copy of artwork is clear				0.5
	grid drawn				1
	intended transformation explained, with scale				0.5
Kite Test					
	Background Information				
		Accurate			1
		Relevant to test			0.5
		Complete			1
		Reference resources			0.5
	Hypothesis / Prediction				1
	Procedure				
		Setting up test			
			Figure with labels		2
			Narrative / List		2
		Measuring / data collection			1
		Data analysis			1
	Results				2
	Conclusions / Discussion				

		Data mentioned & compared to prediction		1
		Clear, concise summary of findings		1
		Possible future studies (not to be done)/problems		1
Documentation of Design				
	Brainstorm (1st homework)			
		Sketch		1
		Features noted		1
		Discussion of knowledge on aerodynamics		1
		A member's work missing(subtract that member only)		-3
		Completed on time (prior score)		0.5
	Web Quest work			
		Answers clear and complete		2
		Quotations / own writing		1
		Completed on time (prior score)		0.5
	Common sketches of design (2nd of 3rd work day)			
		Sketch		1
		Features noted		1
		Completed on time (prior score)		0.5

	Paragraph describing reflection on kite design after kite test			
		Clear, well written		1
		logical, based on data		2
		list of noted changes on blueprint(s)		1
	Photos of group			
		Assembly Photos		1
		Working as a team (on anything)		1
		Flight test		1
		Due date flying (will not be in report)		1
Proof (one for each member)				
	Proof objective clear			0.5
	All 3- columns included			1
	Steps missing			-1
	Assumptions made that are not well founded / explained			-1
	Extra steps			-1
	Appropriate language			
		Postulates and Theorems explained, not numbered		3
		Postulates and Theorems are not accurate		-1
	Original (not already published)			3
	Figure			

		Parts come from kite geometry		0.5
		Only relevant parts included		1
		To scale, neat		0.5
		Labeled appropriately		1
	Test of proof with actual measurements			
		Measurements accurate		1
		Step-by-step (aligns with proof)		1
		Conclusion is reasonably close to that of proof		0.5
		Error is not explained, if it occurs		-1
	Student evaluation			
		Two students evaluate		~
		paragraph feedback		1 x 2
		signatures		0.5 x 2
Contract				
	Signed by all members			1
	Clear responsibilities			1
	Deadlines included			1
	Not amended, but changes were made			-1
	Submitted to teacher on time (prior score)			1
Evaluations (due day after report submitted- each member completes his/her own)				

	Members evaluated numerically			0.5
	Members evaluated in words			0.5
	Project evaluated			
		pros		0.5
		constructive criticism		0.5
		teamwork skills		0.5
		geometry applications		0.5
		careen applications		0.5
	Submitted on time (boc day after due date)			0.5
Kite height calculations				
	Trigonometry work clear			2
	Figure			1
	Submitted on time (boc day after due date)			0.5
Extra Credit				
	Extreme excellence in:			
		Aerodynamic application		0
		Test design and write-up		0
		Construction		0
		Artwork		0
		Report writing		0
		Team work		0
		other:		0
TOTAL:				111