THE Fabric Flight connection

4-H Youth Development
Cornell Cooperative Extension
THE Fabric Flight connection

4-H Youth Development
Cornell Cooperative Extension
The Fabric/Flight Connection handbook was produced by Cornell Cooperative Extension and written by Charlotte W. Coffman, senior extension associate, Department of Textiles and Apparel, College of Human Ecology at Cornell University.

Acknowledgments

Thanks to Bernina Sewing Machine for permission to reprint patterns for the wind socks, to Doug Evans for permission to modify an activity from his book, Oh, Chute!, to John Weber for sharing his tetrahedral kite, to Evelyn Dankovich for contributing kite designs, and to Anil Netravali for introducing a kite from India. Appreciation is due to Susan Watkins, who began this handbook and to Nancy Breen, who authored the videotape of the same title. A special debt is owed to the young adventurers and their adult leaders and teachers who tested these activities and contributed their ideas.

Illustrator: Jim Houghton of Graphic Touch, Ithaca, New York

Designer: Barbara Drogo

Editor: Susan Pohl

Both the Fabric/Flight Connection handbook and the videotape are distributed by Cornell University Resource Center, 8 Business & Technology Park, Ithaca, NY 14850, telephone 607-255-2290, fax 607-255-9946, e-mail <dist_cert@ccs.cornell.edu>, World Wide Web: http://www.cce.cornell.edu/publications/catalog.html

Mention or display of a trademark, proprietary product, or firm in text and figures does not constitute an endorsement by Cornell Cooperative Extension and does not imply approval to the exclusion of other suitable products or firms.
Contents

Introduction

Unit 1. Things That Fly
Boomerangs .................................................. 7
Wind Socks .................................................. 13
Kites ......................................................... 23
Rockets ....................................................... 51
Balloons ....................................................... 61
Parachutes .................................................... 69
Giders ......................................................... 85
Disk-Shaped Objects ....................................... 93
Airplanes ..................................................... 101
Helicopters ................................................... 115

Unit 2. Materials in Flight
Make a Polymer ........................................... 128
Fiber Explorations ......................................... 130
Spider Style .................................................. 133
Human Loom .................................................. 135
Fabric Projections .......................................... 138
Compose a Composite ...................................... 140
Air Permeability ............................................ 142
Elongation and Elasticity .................................. 145
Flammability ............................................... 148
Moisture Response 1 ....................................... 152
Moisture Response 2 ....................................... 154
Strength 1 ................................................... 156
Strength 2 ................................................... 159
Strength 3 ................................................... 162

Unit 3. Apparel for Flight
Space Suit Gloves ............................................ 169
Sew a Stretchy Sack ......................................... 172
Stretch It Out ............................................... 174
Pleats Galore ............................................... 176
Flex Time ................................................... 178
Color Me Hot, Color Me Cool ......................... 180
Are Space Suits as Hot as They Look? .............. 183
Smashing Snickers ......................................... 185
Pickpockets .................................................. 186
Make a Loop Fabric Vest .................................. 187
Velcro Dodgeball ............................................ 189
Build a Space Suit ......................................... 191

Unit 4. Resources
Glossary ..................................................... 195
Sources for Activity Supplies ........................... 199
Sources for Educational Materials .................... 200
NASA Field Centers and Teacher Resource Centers .. 202
Science Education Agencies and Organizations .... 203
Textile Agencies and Organizations .................... 203
Museums ...................................................... 204
References ................................................... 206
Evaluation .................................................... 207
The Fabric/Flight Connection program teaches principles of fiber science through the exciting story of aviation. It also informs youth about nonapparel uses of textiles and encourages them to explore careers in science and technology. Program resources consist of an activity notebook and a videotape. The two resources are complementary but not parallel; each can stand alone or they can be used together.

The handbook provides experiential activities that encourage youth to discover how objects move through the air, to identify the essential characteristics of materials used in these objects, and to understand the importance of design in aircraft and aviator clothing. Projects vary in difficulty to accommodate audiences of many ages. Youths from 5 to 19 years of age have completed these projects. The handbook is printed on white loose-leaf paper for easy photocopying. If you did not purchase this handbook in a three-ring binder, we recommend that you buy one with pockets on the inside covers for convenient storage of patterns.

The videotape contains two 15-minute segments. Part I highlights the historical use of textiles in aviation. It is entertaining and informative for all ages. Part II covers composite materials, polymer science, and aviation-related careers in fiber science and industrial textiles. It was designed for junior high and high school science, technology, and home economics classes as well as for 4-H and other nonformal education groups. The videotape is also appropriate for college and adult audiences.
Handbook Organization

The handbook is divided into four units: flight, materials, apparel, and resources. The first three units begin with a few pages of background information followed by a selection of activities. Unit 4 provides additional information and assistance in program management.

Unit 1: Things That Fly discusses the principles of flight. Readers demonstrate those principles as they make boomerangs, rockets, helicopters, and other flying objects. Activities are grouped chronologically into categories according to their historical use. Although some readers might think rockets are a recent invention, simple rockets predate many of the other flying machines. Hence rockets appear early in Unit 1. Activities within a category range from simple to difficult. The first kite is easy enough for a five-year-old, and the last kite is difficult enough to challenge a teen or adult.

Unit 2: Materials in Flight takes a close look at the fibrous materials used in aviation. Students explore the chemistry and structure of fibers, fabrics, and composites and think about which properties are important in flight. Activities are sequenced from origin to end product. Thus students will learn how the basic fiber chemistry (polymer) creates raw materials (fibers) that can be manipulated into larger materials (fabrics and composites) that have the specific properties (e.g., strength and permeability) needed for flying objects or flight gear.

Unit 3: Apparel in Flight examines the function of garments in relation to materials, design, and construction. Activities in this unit build on the design and fiber science principles in Unit 2. Thus “Stretch It Out” logically follows “Elongation and Elasticity,” and “Smashing Snickers” applies what was observed in “Strength 1, 2, and 3.”

Unit 4: Resources contains a glossary, bibliography, and evaluation form. It also lists suppliers, museums, and agencies with pertinent educational materials. Please remember that suppliers change their inventories, museums change their hours, and agencies change addresses. Always contact them before organizing a field trip or ordering items by mail.

Activities

Activities have been selected based on relevance to the topic, “fun factor” when tested with youth, degree of physical activity, and opportunity for discovery. The goal is for all students to participate, learn, and enjoy.

Age levels are not noted so as to encourage flexibility among leaders and youth. For example, “Flying Saucers” is clearly directed toward children aged five to eight years, yet pilot tests showed that teens also enjoyed the activity when the disks were sailed competitively through a series of hanging hoops.

Readers are encouraged to create, adapt, and modify. Some activities have patterns included in the text or as inserts. All activities have a brief introductory paragraph followed by six sections:

• “Gather these materials” lists supplies in the order they are used.

• “Allow enough time” refers only to the main activity. Add extra time for items from “Don’t stop now.”
• “Try it” is an illustrated, step-by-step instruction guide. Youth learn construction and investigative skills as they measure, classify, and manipulate materials.
• “Don’t stop now” suggests ways of extending the activity by introducing different variables, designing a new activity, developing a community service project, or taking a field trip.
• “Let’s talk—and think—about what happened” encourages youth to analyze data, evaluate products, and ask, “Why?” “Why not?” or “What if?”
• “Tips for leaders” includes safety precautions, supply sources, and hints for making the activity more successful.

How to Use This Handbook

This handbook is a flexible tool. After careful review and some experimentation, leaders should be able to match activities with specific audiences. For a good understanding of the topic, select at least three sequential activities from Units 1 through 3. Other ideas for fitting the handbook to your group’s size and needs include the following:

• Focus on the unit or category of highest interest beginning with the first activity and following through to the last.

• Build independence through take home projects that can be done alone such as “Indian Kite,” “Fashion a Fabric Frisbee,” “Make a Polymer,” or “Make a Loop Fabric Vest.”

• Strengthen cooperation through group-building activities such as “Tetrahedron Kite” and “Human Loom.”

• Improve sewing skills by completing “Sassy Swivel,” “Eddy Kite,” “Stitch a Chute,” and “Sew a Stretchy Sack.”

• Take a break from sedentary programs with the physically active “Oh, Chute” and “Velcro Dodgeball.”

• Enhance existing programs. Unit I complements transportation units in technology classes. “Balloon Blastoff,” “Ballistic Bazooka,” and “The Cork Popper” fit well with 4-H Rocketry.

• Generate excitement about science by demonstrating “Bernoulli’s Principle,” “Paper Chopper,” and “Smashing Snickers” at a local fair.

The Fabric/Flight Connection has been used by all grades at the elementary level and by technology, science, and home and career skill courses in middle and high schools. Summer camps, 4-H clubs, scout troops, after-school enrichment programs, museum workshops, and home schooling are other sites of successful use. Three of these experiences are outlined below:
Elementary School Curriculum Enrichment

More than 400 students aged 5 to 11 (grades K through 5) celebrated a month-long multidisciplinary event based on the Fabric/Flight Connection. Classrooms focused on rockets, astronauts, Amelia Earhart, the aerodynamics of wings, and the space shuttle. Take-home projects included making pinwheels, gliders, and composites. Art classes made exotic birds and explored kite designs. The library featured poetry about flight; the fifth grade performed the musical Sky Happy. The study ended with Flight Night, where parents and students, assisted by 150 volunteers, made 18 different things that fly, created a “Things That Fly” mural, and tried a variety of experiments based on Bernoulli’s principle and autorotation.

4-H Club

Six 4-H club members, aged 12 to 14, designed a one-semester program based on the Fabric/Flight Connection. They completed 12 activities of their choosing, visited museums and a Challenger Center, and demonstrated activities at the local fair.

Career Exploration

A state youth development program organized a three-day career exploration program for teens 15 to 19 years old on a university campus. Youth who chose the Fabric/Flight Connection designed parachutes, kites, and space suits; tested Frisbees and textile properties; learned about the uses of composites; made nylon; and met pilots, skydivers, fiber scientists, chemists, and engineers.

In-Flight Recorder

Just as recording devices monitor cockpit activity for later analysis, users of the Fabric/Flight Connection handbook should note what is tried and what is learned. Completion of the evaluation form in the back of the handbook will help the authors evaluate the program and make appropriate revisions.

Thank you. Enjoy the flight.
Unit 1
Things That Fly

Birds fly. Butterflies fly. Maple seeds "fly" as they fall. With a little help from airborne devices, people, too, can "fly." To build successful flying machines and to control objects that simply fall in the air, humans had to learn the basic principles of aerodynamics. Let's explore the principles of flight, the laws of motion, and some elements of design as we build things that fly.


All about Air

Air occupies space. Check for yourself by inflating a balloon. Was the balloon larger or smaller after you inflated it?

Air has weight. Place an inflated balloon on one side of a balance and an identical, uninflated balloon on the other side. Are they equal in weight?

Air’s weight changes with temperature. Warm air rises because it is less dense than cooler air. That’s why in winter the second floor of a home is usually warmer than the first floor.

Air exerts pressure. Earth’s gravity pulls the air down—onto us and onto everything around us. At the earth’s surface, air presses down on us at more than 14 pounds per square inch; the pressure is less at high altitudes. Air is forced into every space because of air pressure. Objects maintain their three-dimensional shapes because their internal pressure equals the outside pressure.

Air moves. Forces can create or change motion. Thus the force of cool air pushing against warm air or a change in air pressure will influence the direction and strength of the wind. Fans, hair dryers, and other devices can also cause air to move. Faster-moving air has lower pressure than slower-moving air.

Principles of Flight

Flight can be explained as a compromise between four forces: gravity, lift, drag, and thrust. By manipulating the design and materials of flying things, engineers and scientists can emulate nature by emphasizing the forces that deliver the desired result. Just as wings provide sufficient lift for a bird to fly, parachutes provide sufficient drag to slow a race car, and rockets provide sufficient thrust to hurl the space shuttle into space. Let’s look at how these forces work.

Gravity

Gravity is a natural force that attracts objects to the earth. Because of gravity a toy glider placed on a table will not float away. Gravity causes a skydiver to be pulled toward the earth. The effect of gravity increases as the weight of an object increases. Gravity can be overcome by lift and thrust and moderated by drag.

Lift

Lift is the upward force that must be created to overcome the effect of gravity. Bernoulli’s principle explains that faster-moving air has lower pressure than slower-moving air. If an object in an airstream experiences faster air movement (and hence lower air pressure) above and slower air movement (and hence higher air pressure) below, the object will be pushed upward. Lift can be produced by an airfoil, a shape that causes the air to move faster along its curved upper surface. Wings, sails, and propellers are examples of airfoils. Lift must be equal to or greater than gravity for an object to fly.
Drag

Drag, or air resistance, is a natural force in which air resists the movement of an object. The object's size, shape, and texture influence the amount of drag. An object like a disk that has a smooth surface and rounded edges will sail better than one with a rough surface and protruding appendages. Drag can be overcome by thrust.

Thrust

Thrust is the force that must be created to move an object. Thrust follows the third law of motion that for every action there is an equal and opposite reaction. Thus propeller blades push air backward, causing an equal reaction that pulls the plane forward. A jet engine forces hot gases out behind the aircraft, which pushes the jet forward. Thrust must be great enough to counteract drag.

Types of Flight

Heavier-Than-Air Flight

Most activities in this handbook are based on heavier-than-air flight, of which airplanes are examples. All four forces are involved: lift caused by the airfoil of the wings counteracts gravity. Thrust from the engine overcomes drag.

Lighter-Than-Air Flight

Balloons are examples of lighter-than-air flight. They overcome gravity because they are made of lightweight materials that encase a large space filled with heated air that weighs less than the surrounding cooler air.

Falling in Air

A skydiver jumping from an airplane, a maple seed drifting to the ground, a brick being shaken loose from a building—all fall and accelerate through the air at the same rate. If dropped from the same height in a vacuum, these objects would touch the earth at the same time. Although a heavy object is pulled to earth with greater force than a lighter object, the heavier object also has greater resistance to a change in its motion. We do not, however, live in a vacuum, and air resistance is significant for heavier-than-air objects that have a large surface area. A smooth, compact brick will fall very quickly, a winged, rotating maple seed will make a gentle descent, and sky divers can control their speed by means of a parachute.
Laws of Motion

The movement of all objects, both in space and on earth, was explained by the English scientist Sir Isaac Newton in 1686. His findings can be summarized by what are now called the three laws of motion:

The First Law of Motion
A moving object continues moving with a constant speed in a straight line unless an external force acts on it. Likewise, an object at rest remains at rest unless a force is applied to it.

The Second Law of Motion
An object accelerates when it begins to move or speed up. The amount of force needed to make the object move or change its motion depends on its weight. The direction of the object's movement depends on the direction of the applied force.

The Third Law of Motion
Forces always act in pairs. For every action, there is an equal and opposite reaction.

Aerodynamic Design

Thoughtful design of airborne objects is important for function and control. An engineer or designer must consider the shape, construction, materials, aesthetics, use, and flight conditions when creating an aerodynamic craft. Some design terms are given below:

Control surfaces Surfaces that allow the flier to manage the aircraft. They may be nonadjustable during flight as with a parachute vent, airplane fin, and kite tail or they may be adjustable during flight as with a balloon rip panel and airplane rudder.

Dihedral The angle between inclined side structures of an aircraft. The upwardly inclined wings of an airplane or struts of an Eddy kite create a positive dihedral. The downwardly inclined side keels of the sled kite create a negative dihedral. Both positive and negative dihedral angles help stabilize the craft in flight.

The cross struts of an Eddy kite are set in a positive dihedral.

The side keels and long bridle of the sled kite form a negative dihedral.
Skin friction The amount of drag caused by the texture of the airborne object's surface. A smooth surface creates less skin friction than a rough surface, especially at high speeds.

Streamlining Refers to shapes and structural lines that decrease drag. Sharp edges and protrusions are smoothed and rounded, and areas behind the point of surface-air contact are filled. An airfoil is an example of a streamlined structure. It is flat on the bottom and curved on the top. The front or leading edge is longer than the back or trailing edge.

Symmetry Describes the relationship of opposite sides of a plane, line, or point in terms of size, form, and arrangement. The sides of an aircraft need not be identical but they must be balanced for successful flight.
The boomerang was one of the first devices shaped to follow a controlled path through the air. Archaeologists have discovered sport boomerangs dating back to 12,000 B.C. Specimens have been recovered from Egypt, North America, and Europe. Early Australian bushmen threw wooden boomerangs to kill birds and small animals for food. They perfected the design and their skill to ensure that the boomerang would return for quick reuse when it missed its prey. Today their descendants still use boomerangs for hunting, and other people toss the devices around for fun and sport. In 1982, Peter Ruhf threw a boomerang 750 feet out and back with a catch.

Boomerangs are usually flat and curved with two or more distinctive blades or arms. Part wing and part spinning top, the boomerang can fly in loops, figure eights, spirals, and other fancy formations.

The boomerang flies mainly because it is moving quickly and its shape takes advantage of Bernoulli's principle. The curve in the blade provides a longer route for the air flowing over the wing than for the air moving under the wing. To overcome this obstacle, the air above the wing speeds up, causing the air pressure on top of the wing to decrease. The difference between the lower pressure over the wing and the higher air pressure under the wing creates lift.

Upturned wingtips provide stability, applying drag to keep the leading edge ahead of the trailing edge. Weight balance is also important to prevent the trailing edge from pitching too far downward.
Boomerang 1: Mini-Boomer

Nobody knows for certain where the boomerang's shape originated. One explanation is that it was copied from the seed of the zanonia, a Southeast Asian vine. The zanonia seed drops from the plant and glides to a new home to reproduce. The boomerang is a symbol of Australian ingenuity and resourcefulness. You don't have to live in Southeast Asia or Australia to understand how a boomerang works. This one is so small you can even use it indoors.

**Gather these materials:**
- Boomerang pattern (below)
- 3-in. (7.5 cm) square pieces of cardboard (file cards, manila folders, cereal boxes)
- Pens or markers
- Scissors

**Allow enough time:**
15 to 20 minutes

---

**Try it:**
1. Draw boomerang shape on cardboard using pattern (below).
2. Cut out boomerang.

To fly your boomerang, place it on top of your closed hand (see illustration). Flick one end with your other forefinger. To snap fast and hard, hold the end of your forefinger against the middle of your thumb. Then relax your thumb and snap your forefinger forward.

---

**Don't stop now:**
- Try making larger and smaller boomerangs. Compare how they fly.
- Experiment by making one arm a little longer than the other.
- Compare the flight of your boomerang with that of a commercial one.

**Let's talk—and think—about what happened:**
- Did your boomerang return to you?
- What happened when you tried flying larger or smaller boomerangs?
- What did you observe when you increased the size of one arm?

**Tips for leaders:**
- Students usually need two or three tries before they can make the boomerang come whirling back.
- If you are using a commercial boomerang, allow plenty of space and provide supervision.
Boomerang 2: Cross-Stick Whirler

Not all boomerangs have two blades. This cross-stick type has four. When you throw it, it sails up and away, then curves around and comes right back to you. It flies because its four arms work like whirling wings. Use the pattern to make two boomerangs and compare their flight.

Gather these materials:
- Boomerang pattern (p. 11)
- 2 pieces cardboard at least 7 in. (18 cm) square (medium-sized cereal box panels work well)
- Pencil or pen
- Scissors
- Masking tape

Allow enough time:
- 45 minutes to 1 hour

Try it:
1. Tape boomerang pattern to cardboard and cut out first boomerang.

2. Reshape boomerang pattern by cutting along dotted lines at blade tips.

3. Tape reshaped pattern to other piece of cardboard and cut out second boomerang.

4. Bend a smooth upward curve in arm tips of both boomerangs.

Your boomerangs are ready to fly!
To fly each boomerang, hold it straight up and down by grasping one blade between your thumb, index finger, and middle finger (see illustration).

Throw it level and straight ahead, as you would throw a Frisbee. It starts with a backward movement. Move your arm toward your body and bend your wrist sharply the same way. Then move your arm away from your body, flick your wrist, and let the boomerang go.

The boomerang should tilt over and move level as it whirls up and away in a zooming climb, lifted by its spinning arms. Near the peak of the climb, the boomerang should curve around and whirl right back to you, leveling off as it comes near.

You can also throw it at a flatter angle. First hold the boomerang flat. Then tilt it up toward your throwing arm. When you throw it this way, the boomerang won’t move ahead as far, but it will climb steeper and higher.

**Don’t stop now:**
- How far can you throw each boomerang and still make it return?
- Try throwing the boomerangs at different angles. Which is best for your situation? Would you throw them differently if you were outdoors?
- Make other boomerangs from materials of different weights and thicknesses. Styrofoam meat trays are a good choice. Observe how differently they move.
- Invite your friends to a spot landing contest. On a large piece of paper, draw lines to the opposite corners and find the center. Throw your boomerangs and try to get them to land on the center. The one closest gets 100 points, the next gets 50 points, and so on.
- Put several bowls on the floor. Mark them “10,” “25,” “100,” and so on. Your boomerang must land inside a bowl to score.

**Let’s talk—and think—about what happened:**
- Compare the flights of the two boomerangs. How were they alike? Different?
- The edges of the shaped blade provide a better airfoil. Why is the leading edge longer than the trailing edge? Is it important that the leading edges are on the same sides of the blades?
- The curved-up tips help hold the boomerang upright. Did you try flying your boomerang with the tips curved downward?
- To fly best, a boomerang must be made from material of a certain weight and thickness. Outdoor boomerangs are made from heavier materials such as wood. Their weight adds control and steadiness. If you tried different materials, which worked best?

**Tips for leaders:**
- It takes a lot of practice to throw the boomerang properly. Offer plenty of encouragement.
- If the boomerang turns upside down in the air, tilt it more toward your arm. Keep changing the angle of tilt until it goes in the direction you want. The angle at which the boomerang meets the air increases or decreases lift.
- The boomerang with airfoils (leading edges are longer than trailing edges) should produce more lift and fly farther.
- If someone brings a heavy or large boomerang, fly it outdoors.
Boomerang 2: Cross-Stick Whirler Pattern

LEADING EDGE

TRAILING EDGE
Wind Socks

A wind sock is a tapered fabric funnel attached to a standard by a pivot so that it can move with the wind. Also called an air sock, wind cone, or wind sleeve, it indicates the direction from which the wind blows through it. Air is channeled through the wind sock, entering the larger opening and exiting the smaller opening. Streamers provide drag; slits add movement. Wind socks are usually made of ripstop or taffeta nylon because those fabrics are smooth, strong, and lightweight (Unit 2: Fibers: The Foundation of Flight). Their disadvantage is excessive fraying, necessitating that all seams have protective finishes.

The history of wind socks is tied to the history of kites. At the time of the Roman Empire, wind socks made to resemble dragons were tied to high poles to frighten the enemy. In the nineteenth century, Sir George Nares of England invented the drogue, a short, conical wind sock that is used as a kite tail. Wind socks are still used to decorate homes and gardens; their outlandish designs and bright colors are intended to entertain and amuse. But the principal use of wind socks today is to indicate wind direction at small airports or on bridges.
Wind Sock I: Sassy Swivel

If you’re looking for a simple but interesting wind sock design, try the sassy swivel. When you see how it prances in the breeze, you’ll want to make your own!

**Gather these materials:**
- Sassy swivel pattern (insert)
- Tissue paper (optional)
- Tracing wheel (optional)
- Tracing carbon (optional)
- Tape measure or ruler
- Cardboard (optional)
- Straight pins or tape
- 2 pieces taffeta or ripstop nylon, at least ⅜ yd. (35.5 cm), each in a different color
- Scissors or hot cutter
- Pencil or marker
- Liquid seam sealant such as Fray-Check (optional)
- Sewing machine (with zipper foot: optional) or serger (overlock)
- Thread
- 2 ¼ yd. (2 m) 33-mm diameter wire
- 1 ¼ in. (3 cm) rubber tubing, 3 mm inside diameter
- Eyelet (grommet) pliers
- 1 metal eyelet (grommet)
- 3 ½ yd. (3.2 m) nylon line
- 1 swivel

**Allow enough time:**
- 2 ½ to 3 hours
- Allow additional time if participants need to make working patterns or practice using Fray-Check, hot cutters, sergers, or sewing machines.

---

**Try it:**

1. Use sassy swivel pattern to make a working pattern by one of these methods:
   a. Photocopy pattern.
   b. Trace new pattern onto tissue paper.
   c. Draw new pattern onto cardboard (you will need this sturdy pattern if you plan to seal fabric edges with Fray-Check).
2. Add appliqués if desired (see “Tips for leaders,” p. 17).
3. Tape or pin working pattern to taffeta or ripstop nylon fabric.
4. Cut six sections (three sections of each color) in one of these ways:
   a. Pin or tape pattern to fabric. Cut single or multiple sections with scissors adding ¼ in. (6 mm) for seam allowance.
   b. Trace around pattern with a pencil or marker. Remove pattern and cut single sections with hot cutter ¼ in. (6 mm) from marked line. **Note:** Hot cutter will seal together layers that are cut simultaneously! **Precaution:** Ventilate work area.
   c. Trace around cardboard pattern with Fray-Check and allow product to dry. Remove pattern and cut around Fray-Check outline, adding ¼ in. (6 mm) for seam allowance.
5. Arrange the six sections in alternate colors.

---

Pattern reprinted with permission of Bernina
6. Place right sides of sections 1 and 2 together and sew with ¼-in. (6 mm) seam allowance. Sew on sewing machine using zigzag stitch or straight stitch of 8 stitches per inch (2.5 cm). Or use serger with stitch length 2.5, differential feed N, cutting width 2, and tensions 4 to 6.

![Diagram of sections 1 to 6 arranged and joined as shown]

7. Continue joining sections until all six are connected. Do not connect sections 1 and 6 until you have finished seam allowances.

8. If fabric was cut with a hot cutter, treated with Fray-Check, or sewn with a serger, proceed to next step. Finish all other seam edges to prevent raveling. Use your favorite finishing technique or try one of these:
   a. Hem seam edges with sewing machine hemming foot.
   b. Run zigzag stitch along raw edges and trim.

![Diagram of zigzag stitching]

   c. Topstitch with straight or zigzag stitch along seam edge, sewing through seam allowance and body of wind sock. If seam allowances are pressed open, stitch on both sides of seam (double-topstitched seam); if seam allowances are pressed to one side, finish both edges with one row of stitching (welt seam).

![Diagram of double-topstitched seam and welt seam]
9. Join sections 1 and 6 to form a circle. Finish edges of seam.

10. Make casing for wire along straight top edge by turning under first \( \frac{1}{4} \) in. (6 mm) and then \( \frac{1}{2} \) in. (1.5 cm). Sew fold in place, leaving \( \frac{3}{4} \)-in. (2 cm) opening to insert wire.

11. Divide top edge into four equal parts and mark with a pencil.

12. Push wire into casing to form a circle and secure ends with rubber tube.

13. Make a hole in pointed end of each section and join together with metal eyelet or grommet, using eyelet pliers.
14. Make a hole at each of the four pencil markings along top edge. Knot a 15-in. (38 cm) length of nylon line to wire at each hole.

15. Gather line ends together and attach to one end of swivel.
16. Attach remaining length of line to other end of swivel for hanging.

*Hang your wind sock outdoors. It should turn as it catches the wind.*

---

**Don't stop now:**
- Collect instructions for different seam finishes. Try sewing some of these seams and making a book of your samples. Some seam finishes are: pinking, overcast, zigzagged, hemmed, French, mock-French, flat-felled, and self-bound.
- Visit a fabric or craft shop to learn more about fusible fabrics and craft aids.
- Write for additional information on fusible fabrics to Pellon Division, Freudenberg Nonwovens, 119 W. 40th St., New York, NY 10018 or Stacy Fabrics Corp., 38 Passaic St., Wood Ridge, NJ 07075.

**Let's talk—and think—about what happened:**
- Must all the points of the wind sock sections face the same way? Why or why not?
- What would happen if you freed the tapered ends of the wind sock sections from the grommet?
- Why is it important to finish the seams of your wind sock properly?
- Do you need to finish the seams that were sewn with a serger?

---

**Tips for leaders:**
- Supervise the operation of sewing machines, hot cutters, and sergers. If necessary, arrange preliminary instruction.
- Ventilate the work area if you are hot cutting nylon fabric.
- Encourage creativity in color combinations and applied designs.
- An easy method for applying designs to nylon is appliqué. Preshrink the nylon fabric for the design by ironing. Draw a reverse image onto the paper backing of transfer fusing web such as Wonder Under. Fuse the nylon with the Wonder Under. Remove the paper backing and apply the nylon appliquéd to the wind sock.
- Check Unit 4: References, or your local library for additional information on appliquéd techniques.
Wind Sock 2: Turbo Charger

The turbo charger wind sock rotates quickly in the wind because of its conical shape and side slits. You can make this wind sock without a pattern—just draw rectangles directly onto your fabric.

Gather these materials:
- 1 3/4 yd. (1.6 m) each of taffeta or ripstop nylon fabrics in 3 different colors
- Tape measure or yardstick
- Pencil or marker
- Scissors or hot cutter
- Liquid seam sealant such as Fray-Check (optional)
- Sewing machine or serger (overlock)
- Thread
- Straight pins
- 24 in. (61 cm) 33-mm diameter wire
- 1 1/4 in. (3 cm) rubber tubing
- 3 1/2 yd. (3.2 m) nylon line

Allow enough time:
- 2 to 2 1/2 hours
- Allow additional time if participants need to practice using Fray-Check, hot cutters, sergers, or sewing machines.

Try it:

1. Draw a rectangle 4 in. x 60 in. (10 cm x 152 cm) for body of wind sock on each of three fabrics.

   ![Diagram of rectangle measurements]

2. Draw another rectangle 2 in. x 25 in. (5 cm x 63.5 cm) for casing on fabric of your choice.

3. Cut rectangles in one of these ways:
   a. Cut single or multiple sections with scissors by following markings.
   b. Trace along markings with Fray-Check and allow product to dry. Cut sections by following Fray-Check outline.
   c. Cut single sections along marked line using hot cutter. Note: Hot cutter will seal together layers that are cut simultaneously! Precaution: Ventilate work area.

Pattern idea reprinted with permission of Bernina

18 Fabric/Flight Connection: Unit 1. Things That Fly
4. Draw a diagonal line across each wind sock rectangle. Cut along diagonal lines to produce six elongated triangles.

5. Arrange the six triangles in appropriate order to achieve your desired color combination. Join them as follows (see diagram):
   a. Offset or stagger upper edge by 1 in. (2.5 cm).
   b. Leave 4 in. from upper edge (10 cm) unsewn.
   c. Sew next 40 in. (1 m). Pin right sides of sections 1 and 2 together and sew with 1/4-in. (6 mm) seam allowance. Stitch on sewing machine using zigzag stitch or straight stitch of 8 stitches per inch (2.5 cm). Or use serger with stitch length 2.5, differential feed N, cutting width 2, and tensions 4 to 6.
   d. Leave remaining fabric unsewn.

6. Continue joining sections until all six are connected. Do not connect sections 1 and 6.

7. If fabric was cut with hot cutter, treated with Fray-Check, or sewn with a serger, no further finishing is needed. Finish all other seam edges to prevent raveling. Use your favorite finishing technique or try one of these:
   b. Run zigzag stitch along raw edges and trim.

   ![Zigzag Stitching](image)

   c. Secure with a welt seam. Close seam allowances and topstitch with straight or zigzag stitch along seam edge, sewing through seam allowances and body of wind sock.

   ![Welt Seam](image)

8. Join sections 1 and 6 to form a cone, with section 1 offset 1 in. (2.5 cm) higher than section 6. Upper and lower unsewn sections of each panel seam allow you to force fabric into this formation, creating the swivel. Finish seam edges. Turn to right side.
9. To prepare wire casing, turn under 1/2 in. (1.5 cm) along both short sides of casing rectangle. Stitch. Fold casing rectangle in half lengthwise to make a band.

10. With right sides together, match edges of casing to edges of cone panels. Pin and sew. Finish raw edge.

11. Push wire into casing to form a circle and secure ends with rubber tube.

12. Divide top edge of casing into four equal parts and mark with a pencil. Make a hole at each of four pencil markings along top edge.
13. Knot a 15-in. (38 cm) length of nylon line to wire at each hole. Gather line ends together and attach to one end of swivel. Attach remaining line to other end of swivel for hanging.

*Hang your wind sock outdoors. It should turn as it catches the wind.*

---

**Don't stop now:**
- Try making a conical wind sock without slits. Compare the performance of wind socks with and without slits.
- Gather tips on how to sew and care for nylon fabrics. Consult publications at your local library. Read the care labels on nylon garments. Write to Coats & Clark, Dept. E21, P.O. Box 27067, Greenville, SC 29616.

**Let's talk—and think—about what happened:**
- What effect do the slits have on the movement of the wind sock?
- If you made a conical wind sock without slits, what construction modifications did you make?
- How did you decide where to hang your wind sock?
- Did you know that hanging a wind sock in the shade will prolong its life?

**Tips for leaders:**
- Supervise the operation of sewing machines, hot cutters, and sergers. If necessary, arrange preliminary instruction.
- Ventilate the work area if you are hot cutting nylon fabric.
Kites

How would you describe a kite? As a flapping sound overhead? Maybe a dash of warm color against the cool blue sky? A kite is simply a light frame covered with a thin material that is flown in the wind while attached to a long string. Yet kites have a universal appeal. Almost everyone can relate at least one good kite story. Kites come in many shapes and sizes, but they all have a structure that catches the wind, a tether to keep them from blowing away, and a bridle to direct the face of the kite at the proper angle to the wind. Kites are grouped into eight basic types: flat, Eddy, box, compound, sled, parafoil, delta, and rotor.

The first known kite was constructed by the Chinese more than 3,000 years ago as a war tactic to frighten their enemies. Kites have also been used in science. In 1752, Benjamin Franklin used a kite to prove his theory that natural lightning was a source of electricity. In the late 1800s, Lawrence Hargrave’s aeronautical research led to the development of the box kite, which, until the mid-1900s, was used by the U.S. Weather Bureau to record barometric pressure, temperature, and moisture data and to predict the weather. Even the Wright brothers used kites to study the science of flight.

In his book Kiteworks, Maxwell Eden describes a kite as “a heavier-than-air tethered aircraft kept aloft in a perpetual stall by the wind.” To maintain this permanent stall, kites must fly so that much of the kite face is exposed to the wind. The amount of kite face exposed to the wind is called the angle of attack. The angle of attack is regulated at the tow or balance point, which is where the bridle is attached to the kite string. A carefully balanced kite is an example of an airfoil that flies by differentials in air pressure above and below the body (Unit 1: Principles of Flight). Lift keeps the kite in the air, overcoming the downward pull of gravity. A tail provides drag that helps steer the kite through the wind.

The world’s cultures have fashioned kites from an incredible array of both natural and manufactured materials. Frames (struts and spines) have been made from leaves, bark, bamboo, boron, nylon brush bristles, fiberglass, wood, wire, epoxy, plastic, graphite, aluminum tubing, and even plastic drinking straws. Diverse textiles such as paper, nylon, cotton, linen, silk, polyester, and polyethylene have all served as coverings. Lines have been made from silk, cotton, hemp, waxed linen, nylon, polyester, aramid, and polyethylene (Unit 2: Fibers: The Foundation of Flight).
**TERMS**

**Angle of attack** Angle at which the wind hits the face of the kite

**Bridle** String(s) that connect the flying line to the kite and control the angle of attack

**Box kite** Kite consisting of three-dimensional cells in the shape of squares, rectangles, or triangles

**Delta kite** Kite formed by two symmetrical triangles on either side of a central keel

**Eddy kite** Kite with cross struts set in a positive dihedral (Unit 1: Aerodynamic Design) for stability. No tail is required.

**Fighter kite** Kite with a flexible cross strut usually flown without a tail

**Flat kite** Diamond-shaped or hexagonal kite that flies at a low angle and requires a tail for stability

**Flying line** String that attaches to bridle, sail, or keel and holds the kite into the wind. Also called kite string or towline.

**Keel** A stabilizing support that runs lengthwise along the center line. It replaces the bridle in some kites and is usually a triangular piece of the sail material.

**Parafoil kite** Kite that has no rigid supports. Its pocketlike cells are inflated by wind.

**Sail** Material that covers the kite frame

**Sled kite** Flexible kite that lacks lateral stiffeners

**Spar** Frame or supportive structure that maintains a kite's shape

**Spine** Central spar that usually runs from top to bottom of a kite

**Struts** Cross or side spars

**Tow point** Point where flying line attaches to bridle, keel or sail

---

**PARTS OF A KITE**

![Diagram of kite parts]

1. **Front**
2. **Keel**
3. **Sail (Cover)**
4. **Tow Point**
5. **Flying Line**
6. **Back**
7. **Spreader**
8. **Spine**
9. **Strut**
How to Fly a Kite When All Goes Well

Stand with your back to the wind, holding the kite away from your body. Let out some line and push the kite upward.

When the wind catches the kite, pull back and forth slowly on the line. Be careful not to pull quickly or hard because that might cause the kite to dive.

Release additional line until the kite reaches the desired altitude.

Reel in the kite by winding the line slowly and steadily. If the wind is strong, you may have to wind, stop, wind, and stop.

Hints for Flying a Kite When Not Everything Goes Well

Match your kite type and material to the wind speed:

<table>
<thead>
<tr>
<th>Wind Speed (mph)</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kite Type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sled</td>
<td>&lt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eddy</td>
<td></td>
<td>&lt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delta</td>
<td></td>
<td></td>
<td>&lt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Box</td>
<td></td>
<td></td>
<td></td>
<td>&lt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fighter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Kite Material</th>
<th>Light Paper</th>
<th>Light Plastic</th>
<th>Light Cloth</th>
<th>Heavy Plastic</th>
<th>Heavy Cloth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;</td>
<td>&lt;</td>
<td>&lt;</td>
<td>&lt;</td>
<td>&lt;</td>
</tr>
</tbody>
</table>

Ask a friend to help if the lack of wind or the presence of ground turbulence from buildings, trees, or hills causes problems. The helper holds the kite on a taut line about 100 feet (30 m) downwind from the launcher. The helper pushes the kite skyward, and the launcher feeds the line.

Make appropriate corrections:

If the kite won’t rise, remove part of the tail and adjust the bridle to change the angle of attack.

If the kite dives, allow the line to slacken or, if necessary, adjust the angle of attack.

If the kite moves toward one side, check for an imbalance of weight or surface area and for uneven length of multiple bridle.

If the kite moves from side to side, lengthen the bridle, the tail, or both; increase the angle of attack.

If the kite wobbles up and down, remove part of the tail and attach the bridle at a lower point.

If the kite rolls, increase the tail length and check that the kite sides are symmetrical in weight and surface area.

Kite-Flying Code of Safety

- Fly kites in flat, open, unpopulated areas. Never fly your kite near power lines.
- Fly kites away from other kiters. If two kite lines cross, the flyers should walk past one another until the lines uncross.
- Fly kites in clear weather. Never fly your kite in a storm or in the rain.
- Fly kites in a wind speed of 4 to 18 miles per hour (mph). Fly in winds of 18 to 30 mph only if you are an experienced kiter. Never fly kites when the wind speed is greater than 30 mph.
- Fly kites with your feet firmly on the ground. You do not need to run into the wind to launch a kite. Never walk blindly backward.
- Tether the kite with twine or string. Never use wire as line.
- Wrap the line around a stick, dowel, reel, or other round object.
- Wear gloves when flying large kites. Never allow the line to slide through your fingers.
- Avoid air traffic patterns near airports.
- Wear caps, sunglasses, and sunscreen as protection against the sun’s rays.
Kite 1: Paper Fold Kite

If you are looking for a kite that requires inexpensive materials and takes only a few minutes to make, try the paper fold kite. It is especially suitable for young children who are not yet strong enough to handle a larger flier.

Gather these materials:
- 1 sheet 8 1/2 x 11 in. (21.5 cm x 28 cm) paper
- Stapler
- Pencil or marker
- Ruler
- Hole punch
- Tape or adhesive reinforcements
- Kite string (3 yd. [3 m] is enough for children to run along with the kite streaming behind but 60 yd. [54.8 m] is needed to really fly the kite)

Allow enough time: 15 to 30 minutes

Try it:

1. Fold and crease paper along centerline from top to a point about 1/3 the length of the paper to form the keel (do not fold along entire length).

2. Carefully roll (do not fold) top corners back to meet at fold about 1 1/2 in. (4 cm) below top of paper.
3. Staple the two corners to creased fold using one staple placed parallel to fold.

4. Mark a point on creased fold about 1/2 in. (1.5 cm) forward from midpoint of paper. Punch a hole at this point (stabilize hole using tape or adhesive reinforcements).

5. Tie string through hole.

Fly your kite!

---

**Don't stop now:**
- Make a second kite, but make the crease the full length of the paper. How does this kite’s flight compare to that of the first?
- Try making kites of different length:width proportions such as 6 in. x 11 in. (15 cm x 28 cm), 8 1/2 in. (21.5 cm) square, and 8 in. x 6 in. (20.5 cm x 15 cm). Which is the best?

**Let's talk—and think—about what happened:**
- What do you think is the purpose of bringing the top corners together in the construction of the paper fold kite? How does this design affect flight?
- The central crease is called the keel. Do you think the kite needs to be symmetrical—the same size and shape on both sides of the keel? Why or why not?
- Why would a length:width proportion greater than 3:4 not make a good kite?

**Tips for leaders:**
- If you have difficulty making the kite fly, set up a large electric fan and hold the kite in front of the fan on a short string.
- If you use an electric fan, recruit sufficient helpers to ensure safe kite flying.
Kite 2: Straw Kite

Making kites acquaints us with many materials. This kite can be made with tissue or typing paper, but let's try something different—Tyvek. Tyvek is a nonwoven material that is available in hobby or specialty kite stores in three weights: 1025D and 1058D are stiff like paper; 1443R is soft like fabric. Tyvek can be glued or sewn.

Gather these materials:
- Tyvek (a Tyvek mailer yields 2 kites; tissue paper can be substituted)
- Scissors
- Waterproof paints or markers (optional)
- 3 plastic straws
- Cellophane tape
- Elmer's white glue
- Hole punch
- Kite string, 12 in. (30.5 cm) for bridle; 60 yd. (55 m) for flying

Allow enough time:
- 45 minutes to 1 hour

Try it:
1. Cut Tyvek as follows: length = length of straw + 2 in. (5 cm), width = length of straw. Draw colored design if desired.

2. Place one straw lengthwise in center of paper and tape into place.

3. Place second straw on top edge of paper. Glue straw to edge and roll it down paper until it meets center straw tip. Secure with glue.

4. Place third straw on bottom edge, glue, and roll until it meets bottom tip of center straw. Secure with glue.
5. Make bridle by punching two holes near top straw and two holes near bottom straw. Tie bridle string so it is about 4 to 6 in. (10 to 15 cm) from face of kite.

6. Attach kite string to bridle with a slip knot as shown.

7. For tails, cut strips of Tyvek about 1 in. (2.5 cm) wide and glue to kite. In light breezes, use fewer tail sections. In stronger breezes, use more tail strips for added stability.

Fly your kite!

---

**Don’t stop now:**
- Try making different versions of this kite by using different types of paper. Notice how each material affects the flight and durability of the kite.
- Learn more about Tyvek. Did you know that you can recycle your Tyvek envelopes? Did you know that people wear protective coveralls made of Tyvek when they are removing asbestos?

**Let’s talk—and think—about what happened:**
- What are the finished dimensions of your straw kite?
- Do you think the shape of the kite is important?
- How did kites made from other materials behave?
- What would happen if the kite tails were shortened or lengthened?

**Tips for leaders:**
- Collect old Tyvek envelopes to use for kite material.
- Flying problems are usually resolved by adjusting the length of the bridle.
- For additional information on Tyvek, write to E. I. du Pont de Nemours & Co., Wilmington, DE 19898.
Kite 3: Sled Kite

Sled kites date back to the 1950s when William Allison patented his design for a polymorphic kite. A decade later, Frank H. Scott successfully marketed a similar design. He coined the name “sled kite” because his kite was a “flexible flyer,” the brand name of a snow sled popular at that time. Sled kites are easy to fly except in crosswinds. They are especially suitable for studying the forces involved in flight.

Gather these materials:
1 full sheet newspaper or a 25-in. x 16-in. (63.5 cm x 40.5 cm) piece of white kraft or butcher paper, brown paper, or poster board
Strapping tape, 1 in. (2.5 cm) wide or wider
Yardstick
Pen or marker
Scissors
1 plastic garbage bag, 24 in. x 30 in. (61 cm x 76 cm) or larger
2 flat wooden dowels, ¼ in. x 16 in. (6 mm x 40.5 cm) long
Hole punch
Kite string, 2 yd. (1.8 m) for bridle and 60 yd. (55 m) for flying (approximately 5 yd. [4.5 m] more string is needed for bridle variations)
1 wooden stick or cardboard paper towel tube

Allow enough time:
1 to 1 ½ hours

Try it:
1. Tape newspaper or other pattern material to table or floor.
2. Using yardstick and marker, draw a 25-in. x 16-in. (63.5 cm x 40.5 cm) rectangle on paper.

3. Measure 6 in. (15 cm) in from left and right sides of rectangle at top and bottom edges. Mark each of these four points.
4. Draw a straight vertical line to connect points on left side; then connect points on right side.

5. Along the left and right edges, measure 5 in. (12.5 cm) down from top and mark these points.
6. On each side draw two straight lines, connecting the points marked to form a triangle.

Instructions reprinted with minor modifications from Space Station Indiana, Purdue University, 4-H Youth Programs, W. Lafayette, Indiana

30 Fabric/Flight Connection: Unit 1. Things That Fly
7. Cut out finished pattern, which will be a six-sided shape.

8. Lay unopened garbage bag flat on floor or table. Lightly tape pattern to bag and cut around pattern through both layers of plastic. Remove paper from plastic kite shape. You have cut two plastic kites.

9. Construct frame by placing dowels on plastic kite shape, along 16-in. (40.5 cm) base of the two side triangles. Secure dowels with 4-in. (10 cm) pieces of strapping tape, wrapping about 1 in. (2.5 cm) of tape over end of dowel and onto back of kite.

10. Use two more 4-in. (10 cm) pieces of tape to cover side triangle points on front and back of kite. This reinforces bridle attachment point.

11. Punch a small hole ¼ in. (6 mm) in from each side triangle point.
12. Cut a piece of string 1 yd. (91.5 cm) long for bridle. Fold it in half. Rest finger in fold, and ask a friend to tie a knot with the bridle string around your finger. Remove finger from knot, leaving loop in center of bridle. This loop is the towing point.

13. Tie ends of bridle string through holes at side triangle points.
14. Prepare towline by tying one end of kite string securely around wooden stick or paper towel tube. Wrap all but last yard of line around stick.
15. Tie loose end of towline securely to towing point.

Fly the kite outside in a large open area free from trees and wires.

Don’t stop now:
- Try these bridle lengths for your kite: 1 yd. (91.5 cm) and 3 yd. (2.7 m).

Let’s talk—and think—about what happened:
- What is the importance of the bridle? (Unit 1: Kites)
- How do you predict your kite will fly with a shorter bridle? With a longer bridle?
- What is the area of the kite in square inches? Hint: the area of a triangle is 1/2 base x height (A = 1/2 bh) and the area of a rectangle is length x width (A=lw).

Tips for leaders:
- Compare the completed sled kite with a delta kite (purchased or made) to help students understand the difference in structure.
- Use an orange plastic bag with a pumpkin design for instant color.
- If youth have a hard time working with slippery garbage bags, tape the cut shape to the floor or table; weight the plastic shape with rocks, canned goods, or other objects; or substitute newspapers.
- For other interesting activities related to flight and space, send for a copy of Space Station Indiana, available from Purdue University 4-H Programs, W, Lafayette, IN 47907.
Kite 4: Bullet Kite

The bullet kite is a sled kite variation patented by its inventor, Ed Grauel of Rochester, New York, in the 1970s. It has two cells or air channels that minimize the wobble often exhibited by the sled kite. The crescent-shaped leading edge of the cells also improves performance. The bullet is a great climber that is stable in heavy wind or light breezes, and it can be scaled down to 3 inches (7.5 cm)!

Gather these materials:
- Clear plastic garbage bags, 33 1/2 in. x 24 in. (85 cm x 61 cm) for kite face and 19 1/2 in. x 26 in. (49.5 cm x 66 cm) for cell sleeves
- Black marking pen
- Cellophane tape, 3/4 in. (2 cm) wide or wider
- 3 dowels, 3/16 in. x 24 in. (5 mm x 61 cm) long for spars
- Scissors
- Double-sided tape
- Strapping tape
- Hole punch
- Bridle string, 8 ft. (2.4 m)
- 1 spool of kite string

Allow enough time:
1 to 1 1/2 hours

Try it:
1. Draw full-sized patterns of kite face and cell sleeves (based on measurements in diagram) on paper using black marker so outline is visible through plastic.

![Kite Face Pattern and Sleeve Pattern Diagram]

2. Tape patterns (marked side faces upward) to working surface and then tape plastic over pattern.

Instructions reprinted with permission from an article by Margaret Greger in National 4-H News
3. Run cellophane tape along short edges (top and bottom) of sleeve. Cut out sleeve.

4. Lay dowels on face of kite and tape into place. These form the kite's spars. Outline kite with cellophane tape, using short segments on curved edges. Cut out kite.

5. Lay double-sided tape on center spar. Fold sleeve lengthwise in half and place center fold line on tape. Open sleeve and press along spar to seal.

6. Join edges of sleeve to kite face with cellophane tape— one half on sleeve, other half on outer spars and kite face.
7. Reinforce tips of spars with 2-in. (5 cm) strips of strapping tape, over tips at top and base of kite. Repeat with outside corners.

8. Punch holes in outside corners, tie on bridle.

9. Tie loop in middle of bridle (see p. 32 for how to make bridle). Tie kite string through loop to form flying line.

10. Add tail streamers or drogue (small wind sock) for strong winds.

Go fly your kite!

Don’t stop now:
- Decorate the kite by adding designs cut from colored plastic or by drawing with permanent ink markers.
- Try making kites of different sizes by scaling the pattern down or up.

Let’s talk—and think—about what happened:
- Can you guess the purpose of applying cellophane tape to the plastic edges?
- How long would you make the sides of the bullet kite if using 1-foot-long (30.5 cm) dowels? Or dowels 1 yard (91.5 cm) long?

Tips for leaders:
- Use sturdy paper for the pattern so that it can be reused.
- Provide enough space and patterns for each person.
- To facilitate cutting plastic, hold the plastic taut, open the scissors blades only slightly, and cut by pushing the blades against the plastic.
- If you prefer to use ripstop nylon, refer to the cutting and sewing instructions in Unit 1: Wind Sock 1.
Kite 5: Indian Kite

This kite, an unassuming paper and bamboo construction, is sold at affordable prices in markets across India. Close inspection reveals a sophisticated flier steeped in the history of the Asian fighter kite. Kite fighting is described in India's ancient religious writings and can be observed today at the Utran, the largest kite festival in the subcontinent with an annual attendance in the millions. But you don’t have to enter a kite-fighting competition to enjoy making and flying this agile and responsive kite.

Gather these materials:
1 piece tissue paper, 15 in. x 20 in. (38 cm x 51 cm)
Ruler or yardstick
Pen or pencil
Scissors
Rubber cement
1 3/16-in. dowel, 14.5 in. (37 cm) long for spine
Thread, 50 in. (1.3 m) long
1 3/2-in. flexible bamboo piece, wooden stick, or fiberglass rod, 19 in. (48 cm) long for bow
2 toothpicks
1 strip newspaper, 2 in. x 45 in.
(5 cm x 1.1 m)
Bridle string, 32 in. (81.5 cm) long
1 spool kite string

Allow enough time:
1 1/2 to 2 1/2 hours

Try it:
1. Fold tissue paper in quarters.

2. Measure crosswise 7 1/2 in. (19 cm) and lengthwise 10 in. (25.5 cm) from folded corner. Mark points as A and B and draw a straight line between them.

3. Measure 5 in. (13 cm) along each edge from open corner. Mark these points as C and D and draw a straight line between them.

4. Draw a rectangle 1 1/4 in. x 3/4 in. (3 cm x 2 cm) in remaining space.
5. Cut along drawn lines to create a diamond-shaped kite face, triangular stabilizer fins, and rectangular reinforcements.

6. Place dowel along shorter axis (15 in. [38 cm]) of kite body to form spine. Cement securely and dry.

7. Tie one end of thread to bottom of spine. Secure knot with cement.

8. Apply cement along one edge of kite. Place thread on cement about ¼ in. (6 mm) from edge. Fold and seal paper edge to conceal thread.
9. Wrap thread around one end of bamboo bow, tighten loop, and cement.

10. Cement one reinforcement over end of bow at first kite corner. Dry.

11. Cement second reinforcement over bow, slightly above first reinforcement, and dry.

12. Apply cement along edge of next side, place thread, and fold paper edge as in step 8.
13. Wrap thread around top of spine, tighten loop, and cement securely.

14. Apply cement along edge of third side, place thread, and fold paper edge as in step 8.

15. Slowly bend bow toward third corner, being careful not to break the stick. Cement bow at third corner and dry.

16. Secure bow end at third corner with two reinforcements as in steps 10 and 11.
17. Wrap thread around bow, tighten loop, and cement.
18. Apply cement along fourth edge of kite, place thread, and fold paper edge as in step 9.

19. Center one fin on bottom corner of one side of kite so apex of fin is about 1 in. (2.5 cm) from kite bottom. Cement.

20. Turn kite so wooden frame is facing downward. Place two toothpicks on sides of fin and cement them.

21. Cement second fin to first, sandwiching kite body and toothpicks. Discard or share extra fins.
22. Attach newspaper strips to fin.
23. Punch two bridle holes with a toothpick on diagonal sides of bow-spine intersection. Also punch holes on each side of spine at a point 4 1/2 in. (11.5 cm) from kite bottom.

24. Loop one end of bridle string through top holes. Wrap bow-spine intersection and knot. Loop other end of bridle through holes near kite bottom and knot it.

25. Make an overhand knot near middle of bridle so top portion is about 1 in. (2.5 cm) shorter than bottom portion. Attach kite string.

Go out into the wind and fly your kite!

---

**Don't stop now:**
- Decorate your kite using scraps of a friend's tissue paper.
- Try adding fins of different sizes.
- Try making an Indian kite with bows with different amounts of curvature.

**Let's talk—and think—about what happened:**
- The string glued along the kite's edges is called a framing cord. Can you guess its function?
- What did you observe when you used larger or smaller fins?
- Can you predict how the kite will fly if the bow is curved more or less?

---

**Tips for leaders:**
- Construction of this kite requires patience. Make one ahead of time to test the available materials and to become familiar with the technique.
- Purchase the most durable tissue paper you can find.
- Glue with rubber cement to prevent color from fading.
- Allow time for the rubber cement to dry.
- If the bow does not bend easily, train it slowly. Notch the ends of the bow and loop a string between the notches, bending the bow. Tighten the string slowly until the desired amount of curve is obtained.
Kite 6: Flat Kite

The first kite patent in the United States was granted to William Perrins for a flat kite in 1866. Since then, more than 575 kite patents have been issued by the U.S. Patent Office, but the flat kite remains a favorite. Flat kites need tails to supply drag and to keep the body pointed toward the sky. Let's use a woven fabric for this kite. Tightly woven fabrics are durable and won't tear in the roughest winds!

**Gather these materials:**
- Fabric for kite body: 1 yd. (91.5 cm) of 45-in. (1.1 m) wide fabric (cotton poplin, chintz, starched batiste, or other tightly woven, lightweight fabric)
- Marker
- Yardstick
- Fabric for appliqué (optional)
- Scissors
- Iron and ironing board
- Straight pins

**Sewing machine**
- Thread
- 1 package white twill tape, ½ in. (1.5 cm) wide
- 2 dowels, ¼ in. (6 mm) in diameter, 1 yd. (91.5 cm) long
- Handsaw
- 1 spool kite string

**Allow enough time:**
- 2 to 2 ½ hours

---

**Try it:**
1. Draw kite outline directly onto fabric according to measurements in illustration.
2. Cut kite from fabric.
3. Appliqué design to right side if desired (see p. 17 for appliqué instructions).

---

Instructions contributed by Evelyn Dankovich and the Cornell Cooperative Extension office in Onondaga County, New York.
4. Fold bottom point of kite $\frac{3}{4}$ in. (2 cm) to wrong side and pin.

5. Fold all kite edges to wrong side $\frac{1}{4}$ in. (6 mm) and press.

6. Turn under another $\frac{1}{4}$ in. (6 mm), pin, and sew close to inside fold to hem.

7. Cut twill tape into one 50-in. (1.3 m) piece for tail, three 1 $\frac{1}{4}$-in. (3 cm) pieces for bridle and spar reinforcements, and four 6 $\frac{1}{2}$-in. (16.5 cm) pieces for spar pockets.

8. Fold end of tail $\frac{1}{4}$ in. (6 mm) twice and pin to bottom of kite. Double stitch tail to kite, keeping edges of tail and kite even.

9. Fold spar pocket pieces as shown and secure with pin.
10. Pin folded spar pocket to kite corners with opening toward kite center. Sew around pockets twice, \(\frac{1}{8}\) in. (3 mm) from edge.

11. Sew one reinforcement piece over center line, 10 in. (25.5 cm) below kite top.

12. Turn kite so right side is facing up, and sew other two reinforcement pieces over center line, 5 \(\frac{1}{2}\) in. (14 cm) below kite top and 8 in. (20.5 cm) above kite bottom.

13. Cut dowels. To determine length, measure between ends of spar pockets. Vertical dowel should be about 30 in. (76 cm); horizontal dowel should be about 28 in. (71 cm).

14. Pass vertical dowel through spar reinforcement and insert into top and bottom spar pockets.

15. Pass horizontal dowel behind vertical dowel and insert into spar pockets on either side.
16. Cut a length of kite string 38 in. (1 m) long. Measure 16 1/2 in. (42 cm) from one end and make an overhand knot to form bridle.

17. Securely knot shorter end of bridle to reinforcing tape loop sewn near top of right side of kite.

18. Securely knot longer end of bridle to reinforcing tape loop sewn near bottom of right side of kite.

19. Attach end of kite string to overhand knot on bridle to form flying line.

Move into the wind and enjoy the flight!

---

**Don’t stop now:**
- Fly your kite on three different days. Record the wind speed, humidity, temperature, and barometric pressure for each day. Did you note any changes in your kite’s flight?
- Tie bits of colored fabrics (tie weights) to the kite tail. Fly your kite using 2, 6, and 12 weights on each day. Note which number of weights was best. Record the wind speed, humidity, temperature, and barometric pressure. Did you observe any relationship between the optimal number of weights and the climatic conditions?

**Let’s talk—and think—about what happened:**
- What fabric did you use for your kite? Name two characteristics of that fabric that made it a good choice for kites.
- What effect did the weather have on your kite flying? Under what conditions did your kite fly best?
- Describe the flight of your kite with and without tie weights. Which number of weights was best?

**Tips for leaders:**
- It may be helpful for you to make a kite step by step with the students as a visual aid.
Kite 7: Tetrahedron Kite

Alexander Graham Bell, inventor of the telephone, supposedly built the first tetrahedron kites and spent many afternoons flying them with friends and family amid the heather of Scotland's hills. The adaptation we will use was suggested by John and Joseph Weber of Rochester, New York. The tetrahedron kite challenges its builders to learn mathematics and physics, to develop artistic and creative ideas of shape and color, and to work cooperatively with others. Whether flying outdoors or hanging indoors as a mobile, the tetrahedron kite is unique—and the more units you attach, the more grand the kite. One of Bell's kites had 3,393 tetrahedron cells and weighed 208 pounds!

Gather these materials (for one unit consisting of four tetrahedra):
- Wire
- Wire cutters
- Ball of cotton string
- 24 nonbendable drinking straws
- 1 spool kite string
- Measuring tape or yardstick
- Scissors
- Colorful tissue paper
- Rubber cement
- Kite pattern (p. 50)

Allow enough time:
- 20 minutes for the first tetrahedron; about 1 hour for the four-unit kite

Try it:
1. Cut a piece of wire about 10 in. (25 cm) long to use as a needle.

2. Make a small loop at one end of wire. The loop or “eye” of the needle must be large enough to hold the cotton string but small enough to pass through the straws.

3. String together five straws.
4. Pass needle and string back through third straw as shown to make a triangle of straws 3, 4, and 5.

5. Pass needle and string through straw 6.

6. Cut string from ball and tie end to string between straws 4 and 5 to form a second triangle of straws 1, 2, and 5. The two triangles share one common side to create a diamond shape.

7. Remove string from needle, pull string tight, and tie end to the string between straws 1 and 2 to form a tetrahedron.

8. Repeat steps 3 through 7 to make three more tetrahedra.

9. Fold a sheet of tissue paper into halves or fourths depending on size of paper.

10. Place pattern on paper and cut four pieces.
11. Apply a strip of rubber cement along center of one piece of paper. Be careful not to use too much!

12. Lay a tetrahedron edge on cement strip and hold for 20 seconds. This helps to center the paper on the tetrahedron.

13. Let go of the tetrahedron. It will fall to one side. Apply rubber cement to paper flaps and fold over straws.

14. Turn tetrahedron on its other side and glue flaps over the straws. The tetrahedron now has two of its four faces covered with paper.

15. Repeat steps 9 to 14 to cover three other tetrahedra.
16. Place three tetrahedra on table in a triangle with one open side facing the table and the other open side facing you. Use short pieces of string to tie tetrahedra together at the three touching points.

17. Tie fourth tetrahedron on top of the three, making certain open sides of tetrahedron face in same direction as those of the others. Snip dangling strings.

Attach a string to top of fourth tetrahedron and fly your kite.

**Tips for leaders:**
- Use rubber cement instead of glue so the color from the tissue paper doesn’t run.
- You may omit the hooked wire needle. String can be dropped through a vertical straw or pushed through a horizontal straw, especially if the ends are wet or strengthened with beeswax.
- When working in a large group in which string spools must be shared, it may be easier to cut the strings ahead of time.
- Paper clips may be used instead of strings to hold the straws together, but the kite will be heavier.

**Note:** A tetrahedron has three triangular sides and a triangular bottom; a pyramid has four triangular sides and a square bottom.

**Don’t stop now:**
- Make three more kites and assemble into a larger tetrahedron kite!
- Tie your classmates’ units together to make a class kite.
- Decorate your kite with paper of different colors.

**Let’s talk—and think—about what happened:**
- How does the tetrahedron kite differ from other kites?
- Would adding more units on the kite make the kite fly better? Why or why not?
- Why is it important to keep the tetrahedra facing the same direction?
- What are the ratios of covered to uncovered surfaces and the volume of one tetrahedron to the whole kite?
Kite 7: Tetrahedron Gore Pattern

PLACE ON FOLD
Rockets

A rocket is any vehicle propelled by the ejection of gases produced on board by combustible propellants (fuel and oxidant). Because these propellants are self-contained, a rocket can develop thrust independent of its surroundings. Rockets can be solid-propellant such as the Minuteman intercontinental ballistic missiles or liquid-propellant like the Saturn V space booster. The term rocket is sometimes used to describe only the thrust-producing device rather than the entire vehicle, but the more complete term for the propulsion device is rocket engine.

Rocket invention is credited to tenth-century Chinese who fired bamboo tubes stuffed with gunpowder into their enemies’ tents and wicker fortifications. The idea of propelled fire appealed to the Europeans, who used rockets to launch fireworks displays and to ignite the sails of enemy ships. In the 1700s, British officer William Congreve extended the range of the rocket, making it an important factor in the Napoleonic Wars. Nineteenth-century rocketeers pursued peacetime applications such as the transport of lifelines to distressed ships, signaling systems, and propelled lances for whaling.

The use of rockets for space exploration is linked to Russian scientist Konstantin E. Tsiolkovsky, whose vision of space travel became possible in 1926 with the launch of the first liquid-fuel rocket by Robert H. Goddard. In the 1940s, a German team led by Werner von Braun designed the V-2 rocket, the first long-range guided missile. Since World War II, rocket research has centered on intercontinental ballistic missiles and spacecraft-launching rockets. Because no single-stage rocket can reach orbital velocity, today’s spacecraft are equipped with multistage rockets that ignite one by one, exhaust their fuel, detach, and fall back to earth. Some important expendable U.S. rockets are the Atlas, Saturn, and Titan carriers. The space shuttle achieves orbit through a combination of several liquid-propellant rocket engines and two reusable solid-propellant rocket boosters.

TERMS

Casing Tubular structure that is lined with insulation to keep the propellant from burning through

Fins Structures at the base of a rocket near the nozzle that contribute to its stability

Fuel Energy source such as gunpowder, gasoline, synthetic rubber, or liquid hydrogen that burns in the presence of oxygen

Multistage rocket Series of rocket engines constructed so that the biggest engines launch the craft, but detach when their fuel runs out, giving way to successive stages with smaller and smaller engines

Nozzle Opening at the base of the rocket that allows gases to escape from the combustion chamber to the outside. The shape of the nozzle causes the gases to accelerate for maximum thrust.

Oxidant Oxygen-containing substance such as liquid oxygen, nitroglycerin, ammonium perchlorate, or nitrogen tetroxide that causes the fuel to ignite

Payload Cargo carried by the rocket such as passengers, satellites, space telescopes, or warheads

Propellant Combination of fuel and oxygen whose chemical energy is released in the form of heat to provide power
The key to understanding how rockets work is the propellant—a combination of fuel and an oxidant that constitutes about 90 to 95 percent of a rocket’s total weight. The propellants combust to produce gas, which exerts tremendous pressure on the walls of the combustion chamber, except at the rear where it exits. The internal gas pressure pushes the vehicle upward in reaction to the jet of air escaping downward (Unit 1: Laws of Motion). The amount of thrust (Unit 1: Principles of Flight) depends largely on the propellant. Liquefied gases such as hydrogen (fuel) and oxygen (oxidant) are powerful propellants. Solid explosives such as nitrocellulose (fuel) and nitroglycerin (oxidant) are more reliable.

Engines that carry only fuel and use air as the oxidant are called jets. Like rockets, the difference in pressure between the front and back of the jet creates forward movement. Unlike rockets, jet engines cannot function in outer space because they require a ready supply of atmospheric oxygen.
Rocket 1: Balloon Blastoff

British rocket brigades bombarded Fort McHenry in Maryland during the War of 1812, and it was these "bombs bursting in air" that inspired the writing of our national anthem, "The Star-Spangled Banner." Although these balloon rockets don't burst (unless you overinflate or puncture them), they do lose air as they move forward. Make your own rockets and measure the distance they travel.

Gather these materials:
- Ladder (optional: for attaching fishing line to ceiling)
- Scissors
- Monofilament fishing line
- Plastic drinking straws
- Balloons (long, sausage-shaped)
- Masking or freezer tape
- Measuring tape or yardstick

Pen or pencil
Log-in sheet (p. 55)

Allow enough time:
45 minutes to 1 hour

Try it:

1. Fasten lengths (10 ft. [3 m] or longer) of monofilament line to a stable object such as the ceiling, wall, door, or chair. If space allows, provide one line for every two participants.

2. Thread a plastic drinking straw onto each line.

3. Fasten loose end of line to a stable object to achieve three positions: horizontal, vertical, and a 45-degree angle.

4. Assign partners—one to prepare balloon, one to record distance traveled.

5. Inflate balloon to a standard length, depending on size of balloon and length of line.

6. Seal (do not tie!) neck of inflated balloon between your thumb and fingers to prevent air from escaping.

7. With help from your partner, tape inflated balloon to straw. Position balloon underneath straw with its "nose" pointed toward length of string.


9. Repeat same exercise three times for each track. Average results.

10. Make chart (see log-in sheet) comparing average performance along horizontal, vertical, and 45-degree angle track.
Don't stop now:
- Inflate some balloons and release them into the air. How does the action of these balloons differ from the action of the rocket balloons?
- Try taping weights (pennies work well) onto your balloon. How many pennies can it carry?
- Position teams at each end of the string so they can exchange written messages via the balloon rocket.
- Compare performance of rockets made from a variety of balloon shapes and sizes.
- Modify the balloons with attached wings, pointed nose cones, streamers, or other features.
- Organize a rocket race.

Let's talk—and think—about what happened:
- Did the distance the balloon rocket traveled change with the angle of ascent? How? Why?
- What do balloon rockets have in common with a real rocket (Unit 1: Laws of Motion, Principles of Flight, Rockets)?
- How do balloon rockets differ from real rockets? (A rocket carries its fuel and oxidant on board; the interior air of a rocket is extremely hot.)
- What effect did balloon shape and size have on the distance traveled?

Tips for leaders:
- Gymnasiums are great locations because they allow you to create long and dramatically high rocket tracks, but you can demonstrate the balloon rocket in a smaller space, tying the lines to chairs or other furniture. Use small balloons or inflate the balloons less if the line track is short.
- Cotton cord can be used instead of monofilament line.
- If you want to prepare the balloons in advance, inflate each balloon, twist the neck, and secure with a clothespin.
- Adapt this activity as an icebreaker: Write participants' names on balloons and place balloons in a box or bag. Ask each participant to draw out one balloon. Participants interview the person named on the balloon. One by one, have interviewers inflate the balloon, attach it to the straw, and release it. Ask them to give three bits of information about the person named on the balloon before the balloon deflates.
# Log-in

## Balloon Blastoff

### Fiber Characteristics

<table>
<thead>
<tr>
<th>Distance Traveled (in. or cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
</tr>
<tr>
<td>Diagonal (45°)</td>
</tr>
<tr>
<td>Vertical (90°)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test 1</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Test 2</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Test 3</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Total distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Test 1 + Test 2 + Test 3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Total distance divided by 3)</td>
</tr>
</tbody>
</table>
Rocket 2: Ballistic Bazooka

What is a bazooka? Your favorite brand of bubble gum? Well, maybe. But it is also the name of an antitank rocket developed by Clarence Hickman. A World War II infantry soldier could fire the rocket from a shoulder-held tube to an effective range of 200 yards (183 m). Although the bazooka was an important advancement in rocketry, a rocket corps from the Indian state of Mysore manually launched bamboo rockets about the same distance to hold off the British forces in two important eighteenth-century battles. This paper rocket is not as heavy as the bazooka and does not require the skill of an Indian soldier, but you should have fun building and launching it. Compare two launching techniques.

Gather these materials:
- Typing or photocopy paper
- Scissors
- Cellophane tape
- Thick pencils
- Large plastic straws (no larger in diameter than the pencil)
- Soft plastic bottles (e.g., dishwashing liquid bottles)
- Tape measure
- Glue or modeling clay

Allow enough time: 1 hour

Try it:
1. Cut a narrow rectangular strip of paper about 6 in. (15 cm) long and 1 1/2 to 2 in. (5 cm) wide.
2. Roll paper lengthwise around pencil and tape edges along entire length.
3. Slide one end of paper roll forward, fold under 1/4 in. (6 mm), and tape. Seal end completely to form a nose cone.
4. Cut four fins, any size and shape, from a second piece of paper.
5. Tape fins onto paper roll at end opposite nose cone.
6. Replace pencil with straw.
7. Locate an appropriate firing range (open field, gymnasium, or long hallway). Aim rocket away from people.
8. Blow hard into straw to launch rocket.
9. Launch rocket several times, noting distance traveled.

10. Prepare a different launchpad by making a hole in cap of a soft plastic bottle.

11. Insert straw into bottle and seal opening with glue or modeling clay.

12. Place rocket over straw. Squeeze bottle to launch rocket.

13. Launch rocket several times, noting distance traveled.

Don’t stop now:
- Try making the “snack-attack rocket,” so called because people seem inspired to launch them in restaurants while waiting for their food. Open one end of the paper wrapping of a straw (such as the ones used in self-service restaurants) and blow into the straw. The paper sleeve will fly through the air like the paper rocket you just made, but the snack-attack rocket has no fins. Does this make a difference?
- Make fins of different sizes and observe the effect on the rocket’s flight.
- Place the fins at different positions along the length of the tube and note the effect.
- Try different sizes of soft plastic bottles as launchers.

Let’s talk—and think—about what happened:
- How far did your rockets fly?
- Which method of propulsion (blowing or using the squeeze bottle) was most effective?
- What did you observe when you tried different sizes of fins? Or different fin positions? Do you think unbalanced or poorly designed fins would increase drag (Unit 1: Principles of Flight)?
- Which was more streamlined (Unit 1: Aerodynamic Design)—the paper rocket you made with fins or the snack-attack rocket?

Tips for leaders:
- Provide an appropriate space for safe launching.
- Follow up by building a rocket from a purchased kit (Unit 4: Sources for Activity Supplies).
Rocket 3: Cork Popper

Early rockets were powered by a fuel mixture containing the same ingredients as black gunpowder—salt peter, sulfur, and charcoal. This rocket uses a fuel mixture right out of your kitchen, but be careful—never stand in the line of fire!

Gather these materials:
- Colored tissue or cellophane paper
- Scissors
- Cork to fit bottle opening
- Thumbtacks or duct tape
- Baking soda
- Teaspoon measure
- Paper towels
- Water
- Vinegar
- Measuring cups
- Empty soda bottle, quart size

Allow enough time:
30 minutes for a group of five
Because each person should launch his or her rocket individually, more time is required for a larger group.

Try it:
1. Cut streamers 6 to 12 in. (15 to 30.5 cm) long from colored tissue or cellophane paper.

2. Attach streamers to cork with thumbtacks or duct tape. If using duct tape, apply it only to top of cork (taping on side of cork will interfere with secure placement of cork in bottle).

3. Put 1 tsp. baking soda in 4-in. (10 cm) square piece of paper toweling. Twist ends to hold soda inside.

4. Pour 1/2 cup water and 1/2 cup vinegar into bottle.

5. Carry wrapped baking soda and bottle with liquids outdoors to open area with plenty of vertical space for launching.

6. Drop wrapped baking soda into bottle and seal opening with cork rocket.
7. Stand back and wait. Be patient. Do not approach bottle until cork shoots out.

8. Try to estimate what altitude your cork popper achieved.

Tips for leaders:
- Select the launch site with care, and enforce safety procedures during the launch.
- Additional information about the ingredients:
  ✓ Regular strength vinegar is 5.25 percent acetic acid.
  ✓ The chemical formula for acetic acid is \( \text{CH}_3\text{COOH} \).
  ✓ The chemical formula for baking soda is \( \text{NaHCO}_3 \).
  ✓ The chemical formula for carbon dioxide is \( \text{CO}_2 \).
- To explore further the chemistry of how the \( \text{CO}_2 \) gas was produced, borrow a volume of Chemical Demonstrations from a science teacher or your local library or purchase a copy from the American Chemical Society (Unit 4: Science Education Agencies and Organizations).
- To learn more about the strength and absorption of paper towels, order the teacher’s guide Paper Towel Testing from GEMS (Unit 4: Science Education Agencies and Organizations).

Don’t stop now:
- Try another launch, increasing baking soda to 2 teaspoons and vinegar to 1 cup.
- Design experiments to test the strength and absorption of paper towels.

Let’s talk—and think—about what happened:
- Describe what you observed.
- Can you explain why the cork rocket shot out of the bottle? (The liquid slowly soaks the toweling, releasing the baking soda. The baking soda reacts with the vinegar to produce carbon dioxide gas. As more gas forms, pressure builds up inside the bottle. When the pressure is strong enough it propels the cork from the bottle opening.)
- How long did you have to wait for liftoff? Could you decrease the launch countdown time by wrapping the baking soda in a different material? Would that material allow you to engineer a safe launch?
- What happened when you increased the amount of baking soda and vinegar?
- Have you seen other reactions using vinegar and baking soda? (Many youth have used these ingredients to make volcanoes, to inflate a balloon attached to the mouth of the bottle, or to observe “dancing spaghetti.”) If so, can you compare observations with those experiments and this one?
Balloons

A balloon is simply a bubble of gas or air enclosed in an envelope of flexible material. Hot air balloons are used mostly for sport. Gas balloons, which are inflated with hydrogen, helium, or natural gas, are used for sustained travel and to carry instruments that record atmospheric data. Modern blimps are a type of helium balloon used mainly for aerial advertising and for providing camera coverage of outdoor news and sporting events.

French balloon builders Joseph Michel and Jacques Etienne de Montgolfier observed that smoke rising from a candle appeared to lift a small bag and wondered if more smoke could lift a large balloon. Using shredded wool and straw to produce plenty of smoke and a fire that spectator Benjamin Franklin described as "considerable," the ingenious brothers launched their omate, bright blue, seven-story balloon in 1783. Only later was it learned that this first balloon flight owed its success not to smoke but to heat. Hot air balloons gained instant popularity as entertainment and sport but were also put to practical use for transport and military observation.

Frenchman Jacques Charles sent the first hydrogen balloon aloft a few months later in 1783. Gas balloons did not attain wide use until Henri Giffard of France invented the steam-powered

TERMS

Airship A self-propelled aircraft that is lighter than air and can be steered. A dirigible.

Cooling vent Vertical slit at the top of a balloon. It opens to let warm air out, allowing the air inside the balloon to cool and the balloon to land. It is controlled by a cord that reaches from the vent to the pilot.

Envelope The bag that contains the gas or air in a balloon or airship.

Free-floating balloon Balloon that is not anchored to the ground. The pilot controls the vertical movement with the propane burner; the wind controls the horizontal movement.

Gondola Basket or cabin suspended under a balloon or airship.

Gore Tapered shape that is narrow at one end, wide at the other end.

Rip panel Circular panel at the top of a balloon that is opened by the pilot after landing to completely deflate the envelope. It is controlled by a rip cord.

Tethered balloon Balloon that is anchored to the ground by a cable.
balloon in 1852. He fitted a lightweight motor to a balloon with a new easier-to-steer cigar shape. Steel frames were added to create a rigid dirigible. Count von Zeppelin of Germany built huge dirigibles that crossed the Atlantic Ocean. One of these zeppelins, the Hindenburg, exploded in 1937, killing its passengers and ending the reign of the rigid dirigibles.

Balloons are examples of lighter-than-air flight. They float upward because they occupy a lot of space but weigh very little. This is accomplished by inflating the balloon with air or gas that is less dense than the air outside the balloon. Hydrogen, helium, and natural gases are used in gas balloons because they are lighter than air. Hot air balloons are inflated with air that is heated by a propane or butane burner to about 212°F (100°C). As the heated air expands to occupy more space, it becomes lighter than the outside air, allowing the balloon to rise.

Strong, lightweight, nonporous materials are essential (Unit 2: Fibers: The Foundation of Flight) for making a balloon's envelope. Hot air balloons have been fashioned from waxed or varnished silk, rubber, and other textiles. Most modern balloon envelopes are made of nylon fabric treated with flame retardants and other special finishes to resist ultraviolet light, abrasion, and mildew. Early airships were made of silk, cotton, or linen; today's blimps are usually covered with polyester. The Hindenburg was made of cotton fabric coated with rubber. The Earthwinds, an innovative balloon designed in 1991 to carry a crew around the world in a pressurized cabin, coupled a plastic helium balloon with an air-filled superpressure balloon of Spectra polyethylene.
Hot Air Balloon I:
More Than Just Hot Air

Have you ever seen a hot air balloon that was not inflated? If so, you know that all 600 to 800 yards (550 to 750 m) of the envelope fabric can be neatly folded to fit into the gondola. But what happens when it is inflated? Yes, it grows! In fact, the average-sized balloon grows to a height of about 60 feet (18.3 m) and has a diameter of 60 to 100 feet (18.3 to 30.5 m). The balloons in this experiment are not as impressive as the real “wind riders,” but you can observe how air expands when it is heated and compare the size of the balloon before and after inflation.

Gather these materials:
- Balloon(s)
- Tape measure
- Saucepan
- Water
- Hot plate
- Empty glass soda bottle

Allow enough time:
20 to 30 minutes

Try it:
1. Blow up balloon to soften it. Let out the air.
2. Measure circumference (distance around) and length of balloon.
3. Put water in saucepan and place on hot plate.
4. Stretch end of balloon securely over top of soda bottle.
5. Place bottle in water, then heat.
6. Observe balloon until it stops expanding.
7. Measure circumference and height of balloon. How much did it grow?
Don't stop now:
- Try balloons of different sizes and shapes.
- Compare the expansion of balloons made from materials of different weights.
- Try bottles of different sizes.
- View the ballooning section (Part 1) of The Fabric/Flight Connection videotape.
- Research the various textiles used in balloons and exhibit your findings at a science fair, 4-H event, school library, or mall display. Begin the exploration at your local library. Check for articles on silk, polyester, and nylon.

Let's talk—and think—about what happened:
- Molecules move faster when heated. You can see the rapid movement of water molecules when you watch water boil. Air molecules also move rapidly when heated, spreading out to occupy more area. In this case, the air in the bottle expanded to occupy not only the bottle but also the balloon.
- Did you observe any difference in the size of the inflated balloon when you used bottles of different sizes?
- What happened when you tried balloons made from lighter- or heavier-weight materials?

Tips for leaders:
- Caution participants about the danger of working with a hot plate and boiling water, and provide adequate supervision. If necessary, the leader can demonstrate this activity.
- If the bottle tips over in the saucepan, place a little water inside the bottle.
- For information on Spectra, a super-strong polyethylene (Unit 2: Fibers: The Foundation of Flight), write to Allied-Signal, Fibers Division, P.O. Box 31, Petersburg, VA 23804, or call toll-free 1-800-447-3423.
How high can a hot air balloon rise? The record ascent of more than 11 miles (17 km) was established in 1988. Your balloon won’t fly that high, but you can observe how these aircraft lift off by making this simple paper balloon.

**Gather these materials:**
- Balloon pattern (insert)
- Tissue paper
- Pencil
- Scissors
- Glue
- Hair dryer

**Allow enough time:**
45 minutes to 1 hour

**Try it:**
1. Lay pattern on tissue paper and draw around it with pencil.
2. Cut out six gores and fold sides upward.
3. Carefully glue sides of the six pieces together, leaving bottom open. Allow glue to dry.
4. Ask a friend to hold balloon steady. Blow hot air into balloon for at least 1 minute, using hottest setting on hair dryer.

5. Switch off hair dryer and release balloon. It should float upward.

**Don't stop now:**

- Try inflating plastic bags (garbage, grocery, dry-cleaning, or shopping bags). You will need to reduce the size of the opening so that it is not much larger around than the nozzle of the hair dryer (gather extra material and tape or staple it into place). Do not allow the plastic to come in contact with the hair dryer because it might melt.

- Take a field trip to a balloon festival.

- Try out commercial models of hot air balloons and launchers designed for students (Unit 4: Sources for Activity Supplies).
Let’s talk—and think—about what happened:

- Did your balloon lift off? Why or why not?
- What would have made the flight of your balloon more successful? (larger balloon, hotter inside air, colder outside air, and lighter-weight materials)
- A gore is a section of fabric that is narrow at one end and wide at the other. Why is this shape suitable for making balloons? Can you think of other flying objects or products that use gores in their construction? (parachutes, skirts)

Tips for leaders:

- The pattern is based on the standard size tissue paper sold in party and stationery stores. If you have larger sheets, use them—the bigger the balloon, the better it works.
- You might prefer to make a template of the gore pattern from poster board. The template can be placed on several layers of tissue and the tissue cut with a razor blade or knife. This should be done by the adult instructor or by an older youth with adult supervision.
- Do not use more than two hair dryers on one circuit or you may blow a fuse.
- To find out if you have a balloon festival in your area, send a self-addressed, stamped envelope to Balloon Federation of America, P.O. Box 400, Indianola, IA 50125.
The word parachute comes from the French para (preventing) and chute (fall). Thus a parachute is a canopy that traps and holds air to slow the descent of a person or object. Traditional parachutes are umbrella-shaped; modern ones are rectangular or wing-shaped. These parachutes are used for emergency escapes from aircraft, for deployment of military troops, and for skydiving. They average about 24 feet (7.3 m) in diameter. Parachutes designed to drop heavy equipment such as trucks and tanks may measure up to 100 feet (30.5 m) in diameter. Drogue (funnel-shaped) chutes of various sizes are used to decelerate spacecraft, rockets, airplanes, and sports cars. Made from a strong, lightweight fabric such as silk, nylon, or Kevlar (Unit 2: Fibers: The Foundation of Flight), parachutes can be folded into a small pack when not in use.

Leonardo da Vinci drew sketches of parachutes, but the first functional parachute was invented by Frenchman Jean Pierre Blanchard. He dropped a canine parachutist from a balloon in 1785 and made the first successful human jump in 1793. Better known was French aeronaut Jacques Garnerin, who descended 3,000 feet (914 m) from a balloon in 1797. After those early

**TERMS**

**Canopy** Cloth portion of the parachute that fills with air

**Gore** Tapered or flared section of fabric that is narrow at one end and wide at the other

**Payload** Person or object carried by the parachute

**Rip cord** Metal line that when pulled causes the parachute to open

**Suspension or shroud lines** Strings or cords sewn into the seams between the canopy panels. They transmit the drag from the canopy to the falling object.

**Vent** Small opening at the center of some parachutes. It opens when the canopy opens to lessen the jerk that the jumper feels when air rushes into the canopy.
jumps, parachutes became a routine part of a balloonist's equipment. They were used in World War I as lifesaving devices for airplane pilots and passengers. In World War II, extensive use of paratroopers (parachute troops) helped armies penetrate enemy lines. Parachutes continue to provide mobility for people and goods to remote or inaccessible areas, but they also have entered the world of sport. Skydiving became a popular pastime in the 1970s.

A parachute works by trapping air to produce the aerodynamic force of drag. The amount of drag depends on the weight of the object being pulled to earth by gravity, the size of the parachute, and the air permeability of the canopy. Most parachutists open the chute after they have fallen clear of the plane, but some prefer longer free-fall periods. Once the parachute is open, the jumper descends at a rate of about 17 feet (5.2 m) per second. Today's increasingly sophisticated parachutes have control cords that allow the parachutist to speed or slow the descent, turn, and even hover.
Parachute I: Oh, Chute!

Imagine yourself as a parachutist and you probably see yourself floating through blue sky and white clouds. The parachute in this activity, however, is used by keeping your feet solidly on the ground. Doug Evans's book Oh, Chute! explains how a group can use a parachute canopy for physical fitness and for team building. Try this adaptation of one of his activities as an ice-breaker or as an introduction to the topics of parachutes, Frisbees, or properties of textiles.

Gather these materials:
- Energetic participants (10 to 30, depending on size of canopy)
- Parachute canopy
- Sailing disk (Unit 1: Frisbee and Friends or Fashion a Fabric Frisbee)

Allow enough time: 15 to 30 minutes

Try it:

1. Space participants evenly around parachute canopy.

2. Participants grasp canopy in an overhand grip (palms down) with both hands. Inflate canopy by lifting it overhead in unison.

3. Practice inflating and deflating a few times.

4. Give sailing disk to one participant. This person is the first thrower.

5. Count to three, then inflate canopy. While canopy is aloft, thrower sails disk under canopy to another participant, who tries to catch it before canopy falls. It is helpful and safer if thrower calls out catcher's name.

6. Inflate canopy again while disk is thrown to another participant. Continue until all participants have caught the disk.

Adapted with permission from Oh, Chute! by Doug Evans
Don’t stop now:
- Repeat the activity, but have participants offer a response in addition to or instead of catching the disk. For example, if the activity is used as an icebreaker, participants could state their favorite color, spell their name backwards, or provide some other personal information. If it is an introduction to parachutes, participants could name one thing they hope to learn about parachutes. If the activity is used for relief between study sessions, participants could review what they have learned by recalling an aerodynamic force (Unit 1), naming a textile property important to flight (Unit 2), or listing an important design feature of flight apparel (Unit 3).

Let’s talk—and think—about what happened:
- Estimate how long the canopy stayed aloft when it was inflated. What characteristics would be necessary for it to remain inflated longer?

Tips for leaders:
- Provide plenty of space. A gymnasium or outdoor location is best.
- Older youth might use a Frisbee with proper supervision and a safety reminder, but a Whoosh, Sqwish, or other soft-sailing object is preferred.
- Commercial canopies can be purchased at some sports or education supply centers or by mail order (Unit 4: Sources for Activity Supplies).
- If your group cannot afford to buy a parachute, you might sew one, buy a large piece of a flexible material, or simply use a sheet or large tablecloth. The players’ tight grips and energetic shaking may tear the fabric, so select strong materials or salvaged items that can be discarded when they are no longer useful. The larger your group, the larger the canopy you will need.
- Books and records by Doug and Gloria Evans may be ordered from Fun & Fitness (Unit 4: Sources for Activity Supplies).
Parachute 2: Bail Out

Some people say that the idea for the parachute derived from the umbrella, but before you decide to play Mary Poppins, you should consider an important aerodynamic force—drag. The heavier the payload, the less the effect of drag and the faster the fall. Make this simple parachute and drop it with payloads of different sizes.

Gather these materials:
- Handkerchief or other square of fabric (1 piece per parachute)
- 4 strings at least 12 in. (30.5 cm) long
- Film canisters or plastic containers with snap-on lids
- Miscellaneous items to add weight by increments (e.g., popcorn, beans, washers)

Allow enough time:
- 45 minutes to 1 hour

Try it:
1. Gather corner of handkerchief or fabric, wrap piece of string around point three times, and tie. Repeat for other corners.

2. Bring ends of strings together, trying to make them equal in length, and tie an overhand knot.

3. Place knotted string ends inside film canister and fasten lid.
4. Wrap strings around canopy and toss it in the air. Practice until canopy opens and canister floats to the ground.

5. Repeat several times, loading more weight into canister with each toss.

6. Rank speed of descent of each trial and compare. For example, first place (fastest) carried 25 beans; second place, 15 beans; third place (slowest), 5 beans.

Don't stop now:
- Repeat drops, but add extra weight to the parachute instead of the canister. Add weight by applying metallic tape, cloth appliqués, painted designs, or glued objects.

Let's talk—and think—about what happened:
- Did all the parachutes open?
- What happened if the parachute strings crossed?
- Did you toss the parachute to the same height every time? What worked best—a high toss or a low toss?
- What happened when you added weight to the canister? Was it harder to toss? Did the parachute open better? Did it drop faster or slower?
- What happened when you added weight to the parachute canopy?

Tips for leaders:
- Provide plenty of space for throwing parachutes.
- Offer assistance in wrapping the strings around the parachute.
Early parachutists had little control over their descent. Depending on their equipment and weather conditions, they might have fallen in a straight vertical line or been carried a long way from their intended destination. Today’s parachutes provide more control, and weather reports are more reliable, so it is common to see jumpers touching down directly onto landing targets. Nonetheless, skydiving still involves an element of chance. Make this round parachute and experiment with dropping it on a target.

**Gather these materials:**
- Plastic garbage bag
- Scissors
- Self-adhesive labels (8 per parachute)
- Yardstick
- Hole punch
- 8 pieces string, 6-ft. (1.8 m) long per parachute
- Rings (e.g., key rings, curtain rings, washers)
- Small dolls or animal figures
- Chalk or hula hoop

**Allow enough time:**
- 45 minutes to 1 hour

**Try it:**

1. Cut along folds of plastic garbage bag to make a flat piece.

2. Fold opened bag in quarters and cut a curve through all four layers.
3. Bend self-adhesive labels around edge of circle in eight evenly spaced places. Punch a hole in each folded label. Loop strings through holes, using lark's head knots, making sure ends are even.

4. Gather ends of strings together and tie to curtain ring or large paper clip.

5. Tie doll or animal figure to ring.

6. Draw a circle on the ground with chalk or use hula hoop to define target. Drop parachute from balcony, upper-story window, deck, or ladder of a slide. Try to make parachute land inside circle.

**Don’t stop now:**
- Drop the parachute from different heights and compare the results.
- View a videotape about skydiving.

**Let’s talk—and think—about what happened:**
- Did your parachute land inside the target on your first drop? What did you do on the second drop to improve your accuracy?
- Was it windy? Did (or would) wind affect the parachute toss or the parachute flight?
- What could you do to make your parachute drop in a more vertical line? (more weight, larger vent, more porous fabric)

**Tips for leaders:**
- Enlist sufficient adult help and establish a system to provide a safe drop site. For example, one leader can accompany two paratroopers to the drop site while the others remain safely at the landing site. Those on the ground can observe or score the results.
- Borrow a videotape on skydiving from your local library or rent one from a video store.
Airlifting food into a famine-stricken area or medical supplies into a camp devastated by illness requires that the payload arrive safely. Choose the parachute material that you think will carry an egg safely to the ground.

**Gather these materials:**
- 1 yd. (91.5 cm) square pieces of at least 3 different fabrics
- 8 pieces string, 24 in. (61 cm) long
- 2 egg carton cups
- Hole punch
- Masking tape
- Twist ties (from bread bags)
- Scissors
- Boiled egg

**Allow enough time:**
45 minutes to 1 hour

**Try it:**

1. Select a fabric you think would make a good parachute.

3. Fold diagonally to form a triangle, making certain that three folded edges are on one side (A) of the triangle and eight raw edges are on the other side (B).
4. Fold again by aligning side (A) with side (C). Note that the top eight layers of fabric are shorter than the bottom eight layers.

5. **Caution!** Before cutting, make certain that you can count 16 fabric edges at the open end of the triangle. Cut across the eight bottom layers, making them even with the eight upper layers.

6. If you want a vent in the parachute, snip off 1/4 to 1 in. (0.6 to 2.5 cm) of the apex.

7. Open your parachute and tie a length of string to each of its eight points.
8. Punch a hole in all four corners of the egg carton cup. Tie ends of two adjacent strings in each hole. Be careful not to cross strings.

9. Insert one hard-boiled egg in egg carton cup.

10. Invert a second egg carton cup over egg and tape cups together.

11. Bring strings together just above egg cup and secure with twist tie or masking tape. This holds cup upright and prevents strings from tangling.

Drop the parachute and see if your egg survives.
Don't stop now:
- Make several parachutes from different fabrics. Compare their performance.
- Make parachutes from the same fabrics but of different sizes.
- Make parachutes with different-sized vents and with more than one vent.
- Research Kevlar, an aramid fiber popular for parachutes, or one of the fabrics used in your parachutes.

Let's talk—and think—about what happened:
- Which fabrics performed best as parachutes?
- List three important fabric characteristics for an effective parachute.
- Did the weight of the fabric affect the way the parachute fell? How?
- Did the texture (smooth, rough) of the fabric affect the way the parachute fell? How?
- Did you observe any difference between the fall of the parachutes with and without vents? Can you guess the function of the vent? (The vent is mainly for stability and control, although a very large vent can increase the speed of the fall.)
- What is the effect of parachute size? Who needs a larger parachute—a 70-pound person or a 100-pound person?

Tips for leaders:
- Provide a suitable drop site and plenty of landing space.
- Parachute testing works best if at least one adult is at the drop site and a second adult is at the landing site.
- Explore a broad range of fabrics that differ in weight, air permeability, texture, and strength. For example, compare netting, velvet, vinyl, and ripstop nylon.
- If many fabrics are investigated, some will work better than others. This makes the exercise interesting and educational, but young children may need to take home a parachute that works. Consider an experimental set of fabrics for the group activity and a take-home kit of urethane-coated nylon ripstop for each individual.
- Young children may prefer to work with a pattern rather than cut the parachute directly from the cloth. Follow steps 2 to 6 to create a pattern from newsprint, tissue, wrapping, or brown paper.
- Several suppliers carry parachute fabric (Unit 4: Sources for Activity Supplies).
- For information on Kevlar, visit a sail manufacturer or store or write to E. I. du Pont de Nemours & Co., Textile Fibers Department, KEVLAR Special Products, Centre Road Bldg., Wilmington, DE 19898, telephone: 1-800-4-KEVLAR.
Parachute 5: Stitch a Chute

Sewing a parachute can help develop skills in sewing and evaluating seams and buttonholes. It can also develop problem-solving skills and provide design experience. Most parachutes are constructed of panels or gores. Use the pattern provided or redraw it for larger or smaller parachutes.

Gather these materials:
- Fabric, 28 in. x 20 in. (71 x 51 cm)
- Gore pattern (p. 84)
- Scissors
- Straight pins
- Sewing machine (with buttonhole attachment, optional)
- Thread
- Glue (optional)
- Decorations (optional)
- Metal eyelets and eyelet pliers (optional)
- 8 pieces string, 30 in. (76 cm) long each
- Payload items (spools, wooden beads, corks, paper cups)

Allow enough time:
2 to 4 hours

Try it:
1. Fold fabric in half so that it measures 28 in. x 10 in. (71 cm x 25.5 cm).
2. Pin gore pattern to fabric and cut eight gores.
3. Sew pieces together along straight sides, making a circle. Use 5/8 in. (1.5 cm) seam allowances. The parachute will not lie flat; edges tend to roll under.
4. Apply decorations such as machine appliqué, painted designs, or glued craft jewels. Try to distribute heavy decorations evenly across parachute.

5. Make buttonholes adjacent to each seam at outer edge. You may substitute metal eyelets.

6. Tie one end of each piece of string to parachute by threading it through buttonhole or eyelet.

7. Attach string ends—being careful not to cross them—to the object you want to drop. Items with holes (spools or wooden beads) or items in which holes can be made (corks or paper cups) are good choices because you can pass string ends through and secure them with an overhand knot.

*Drop your parachute from an appropriate drop site.*
Don’t stop now:
- Make a gored parachute as a sewing sampler—use different seams (e.g., flat felt, French), fabrics, and embroidery stitches.
- Read about different seams to learn which is strongest.
- Read about different button-hole techniques.
- Examine a real parachute and note seams and other construction details.

Let’s talk—and think—about what happened:
- What fabric did you use? Describe its fiber content, thickness, and texture.
- What seams did you use in your parachute?
- Did you encounter any sewing problems?

Tips for leaders:
- Test sewing machines before the activity.
- Enlist helpers if sewers are inexperienced.
- Take a field trip to a fabric store and allow participants to select their own fabrics.
- Contact your local fabric or sewing machine retailers about possible free demonstrations of sewing techniques.
- Contact your local skydiving organization to arrange a visit by a skydiver, or secure permission to examine a parachute.
- Order Seams and Seam Finishes (#2251) from Coats & Clark, Dept. E21, P.O. Box 27067, Greenville, SC 29616.
Parachute 5: Stitch a Chute Pattern
Gliders

A glider is a heavier-than-air aircraft that moves through the air without an engine. Modern gliders typically have three parts: long, slender wings; a smooth, tapering body; and a stabilizing tail assembly. They become airborne by being towed to a desirable altitude. Sailplanes are gliders designed to sustain flight at flat angles. Hang gliders are kitelike fabric wings that pilots attach to their bodies before jumping from an elevated point. Gliders are made of wood, aluminum, or fiberglass; hang gliders suspend fabric over a supporting frame.

Historians have written evidence of gliders from ancient Egypt (2500–1500 B.C.), but the earliest surviving illustrations were drawn by Emanuel Swedenborg of Sweden in 1714. In 1804, Sir George Cayley of England built a glider model based on the revolutionary design of a long pole crossed by a fixed wing and a cross-shaped tail. In 1853, Cayley sent his coachman hurling down a steep hillside in a boatlike vehicle suspended below a large wooden framed wing covered with cloth. This first recorded glider flight lasted less than a minute but was sufficiently terrifying to cause the coachman to resign.

If Cayley provided the design, German inventor Otto Lilienthal implemented it. Lilienthal made more than 2,000 flights from 1892 to 1896. He learned to control his speed and direction somewhat by shifting his weight while in flight and was preparing to test mechanical controls when he died in a gliding accident.

Giders were overshadowed by the discovery of powered flight, but their popularity has surged with late-twentieth-century interest in efficient flight and personal adventure. In fact, this century has produced a craft that the early glider pioneers were seeking—one capable of sustained flight with human power. The pedal plane *Daedalus 88* is propelled by the 2-horsepower output.

---

* Featured in *The Fabric/Flight Connection* videotape (Unit 4: Sources for Educational Materials, Cornell University)
of a pedaling athlete and kept aloft by a mere \( \frac{1}{2} \)-horsepower of pumping. This dream began with the glider but was not realized until the development of special composite materials (Unit 2: Composites).

Because gliders are not powered, they need help to become airborne. Launch assistance may come from a crew or truck that tows the glider like a kite until it is caught by the wind, from a plane that tows the glider into the sky, or from the natural altitude of a cliff or hillside. Once the glider is in the air, it uses its low weight and large wing area (Unit 1: Aerodynamics) to resist gravity and ride the air currents. Gravity, however, produces sufficient speed to maintain air pressure differences around the wings and create lift (Unit 1: Principles of Flight). Gliders move upward on updrafts and on the winds blowing off hills.
Glider 1: A Current Event

Because a glider has no engine and is carried along by air currents, it is not expected to stay in the air for very long or to move very quickly. You might be surprised to know that, although most glider flights range from one to five hours, the longest recorded flight was 70 hours! And what about speed? Can you guess the cruising rate of a glider? About 50 miles (83 km) per hour. Your glider will not move that fast or stay in the air for more than a few minutes, but you and your friends can build and race your gliders, creating your own "current event."

Gather these materials:
1 piece 8 1/2 x 11-in. (21.5 cm x 28 cm) typing paper
Stapler
Stopwatch
Tape measure or ruler

Allow enough time:
15 to 20 minutes

Try it:
1. Fold and crease paper along centerline from top to a point about 1/3 the length of the paper (do not fold along entire length).

2. Carefully roll (do not crease) top corners back to meet at fold about 1 1/2 in. (4 cm) below top of paper.
3. Staple the two corners to creased fold using one staple placed parallel to fold.

4. Sail glider by holding it at the fold, aiming nose slightly downward and gently pushing it forward. Practice until you attain a long, smooth flight.

5. Time flight and measure distance traveled.

---

**Don’t stop now:**
- Try folding paper airplanes (gliders!) of your own designs, from patterns in books, or from kits.
- Visit a glider show and sketch the different gliders. What did you notice about their shape(s)?

**Let’s talk—and think—about what happened:**
- List some aerodynamic features that increase the air resistance of the glider (Unit 1: Principles of Flight).
- What provides the thrust for this glider? (your arm)
- Why should the nose of the glider point slightly downward? (so that the force of gravity can produce the speed needed to create lift)
- Will the glider travel farther if you throw it harder? (No, a hard throw may provide a burst of initial speed but the glider will float on the air currents and be pulled slowly by gravity to the ground regardless of the force of the throw. More important is a smooth, even release.)
- This same pattern was used in Kite 1, Paper Fold. Why is it appropriate for a glider and a kite to have the same design?

**Tips for leaders:**
- Various paper sizes can be used, but pieces 8 in. (20 cm) square or larger work best.
- Check your local library for interesting paper airplane or glider designs and patterns.
Glider 2: Hanging Tough

The saga of our desire to fly like a bird is told in myth and fact. Daedalus (de-dal-es), a craftsman in Greek mythology, fashioned wax and feather wings for himself and his son, Icarus, who flew too close to the sun and died. In eighteenth-century Europe, artists entertained and inspired the public with sketches of bird suits. But it was German inventor Otto Lilienthal (1848–1896) who first shared the sky with the birds. He mastered the art of gliding because he learned the importance of balance. Try your hand at balancing a figure on this hang glider.

Gather these materials:
- 4 plastic straws
- Square pieces of plastic (garbage bag) cut the length of the straw
- Cellophane tape
- Scissors
- String
- Toy figure

Allow enough time:
- 30 minutes to 1 hour

Try it:
1. Tape first and second straws along two adjacent sides of plastic square.

2. Fold square in half diagonally, bringing together sides with straws.

3. Snip off ⅓ in. (9 mm) of point where straws meet. Cut through straws and plastic.
4. Slide about \( \frac{3}{4} \) of third straw into fold of plastic.

5. Unfold carefully, keeping third straw in the middle. Tape into place.

6. Secure fourth straw across plastic, connecting ends of first and second straws. Tape only at corners (A) and (B).

7. Trim middle (third) straw even with fourth straw.

8. Trim plastic along triangle base as shown.
9. Tape middle (third) straw to fourth straw, being careful not to catch plastic.

10. Tie or tape figure to middle straw.

*Fly your glider!*

---

**Don't stop now:**
- Try moving the figure back and forth and observe the effect of its placement on the flight of the glider.
- Hold a distance competition. Set markers every 10 feet (3 m). Participants sail each hang glider three times. Average the distances and name a winner.
- Make a larger glider by splicing straws together and cutting larger fabric squares.
- Replace the plastic with lightweight fabrics such as organza or nylon and evaluate the new glider.

**Let's talk—and think—about what happened:**
- What happened when you moved the figure forward?
- What was the longest distance any glider achieved?

**Tips for leaders:**
- Encourage careful construction and use plenty of tape to ensure the glider's stability.
- Organize a safe procedure and allow sufficient space when testing the glider.
- If the glider nose-dives, move the figure back. If it stalls, move the figure forward.
Disk-Shaped Objects

A disk or discus is a flat, circular plate that is thrown for distance in athletic competitions. In 1983, Yuri Dumchev threw the discus 283 feet and 9 inches (86.5 m). Long before the Olympics, of course, people were throwing things, their success more a function of skill than the characteristics of the object. All that changed in 1890 with the introduction of rubber and the subsequent development of other lightweight materials such as pressed metal and plastics.

Disks fall through the air at varying speeds, but thanks to their aerodynamic shape, their flight can be sustained under the proper conditions. For the Frisbee, one of those conditions was the advancement in plastics. When Fred Morrison began tinkering with a flying saucer in 1948, he worked with metal but soon moved into butyl rubber and polyethylene plastic. In 1955, Morrison sold the business to the Wham-O Manufacturing Company, which adopted the name Frisbee, selling millions. Other sailing disks soon followed.

The wonder of the Frisbee is that it can sail in a straight line. This is possible because the thick rim creates a turbulence that causes the lift to focus on the disk's center of gravity. The stability required for a straight throw is provided by drag, but drag limits the speed and range. Alan Adler introduced low-drag disks shaped like rings, first the Skyro in 1980 and then the Aerobie in 1984. The Skyro was a high achiever but was stable at only one speed. The Aerobie is a super achiever at any speed because the small lips or ridges along its outside edge solve the problem of balance.
What is the best shape for a flying saucer or an unidentified flying object (UFO)? Most people think flying saucers—if they exist—are oblong or round disks. Just for fun, let’s make a flying saucer. We’ll start with a round plate, but you can make your UFO any shape you like—as long as it will sail. Try decorating it, too.

**Gather these materials:**
- Paper plates
- Tape or stapler
- Scissors
- Glue
- Tissue paper
- Aluminum foil
- Crayons
- Markers
- Glitter
- Stickers
- Reflective tape
- Tinsel
- Paper clips

**Allow enough time:**
15 to 30 minutes

**Try it:**
1. Staple or tape two paper plates together so inside (eating) surfaces face.

2. Decorate your “UFO” with
   - drawn, colored, or cutout designs
   - stickers (stars are great)
   - glitter (draw design with glue; sprinkle with glitter)
   - tinsel or reflective tape
   - foil or tissue streamers

Sail your saucer outdoors or in a spacious room.
Don't stop now:
- Hold a distance competition. Set markers every 10 ft. (3 m). Participants sail each UFO three times. Average the distances and name a winner.
- Try plates of different sizes and weights. Chart the distances for each and compare.
- Create as many interesting shapes as you can.
- Make notches in the plate edges.
- Add weights such as paper clips.
- Use reflective tape or glow-in-the-dark stickers and sail the saucers at night.
- Try to sail your saucer through suspended hoops of different sizes (hula, quilting, and embroidery hoops).

Let's talk—and think—about what happened:
- How many different saucer shapes did you make? Which sailed the farthest? Which sailed in the straightest line?
- Did the weight of the plate affect the way the flying saucer sailed? How?
- In what other ways did you change the weight of the flying saucer? Was it important to place the weights evenly around the plate?
- Did the streamers affect the speed or balance of your UFO?

Tips for leaders:
- Provide plenty of space to avoid collisions.
- Foil or heavy paper plates can be used singly but lack the disk shape associated with UFOs.
- Although this activity was designed for younger children (5 to 8 years old), older students always enjoy the first, sixth, and seventh variations under “Don't stop now.”
Disk 2: Frisbees and Friends

Throwing and catching are basic skills that have entertained humans for millennia. According to John Cassidy in The Aerobie Book, Frank Aquilera set the Frisbee throwing record of 550 feet in 1984. You don’t have to compete with a titleholder. Just predict which object will sail farthest and justify your answer.

Gather these materials:
- Foil pie plate
- Paper plate
- Frisbee
- Whoosh
- Aerobie
- Squish

Allow enough time:
30 to 45 minutes

Try it:
1. Examine flying objects and predict which one will sail farthest. Explain why you selected that object.
2. Throw each object three times, average distances, and compare. Did you predict correctly?

Don’t stop now:
- Test only one variable. For example, use only Frisbees but have three different sizes.
- Try to sail the objects through suspended hoops of different sizes.
- Take a field trip to view a Frisbee contest, or organize one for the school or community.

Let’s talk—and think—about what happened:
- Which object sailed farthest? Can you guess why? Can you design an experiment to test your theory?
- What do you think is more important: design (size, shape) or materials (weight, rigidity, texture)?

Tips for leaders:
- Vary test objects according to availability. Other suggestions are Skyro, Fling Thing, and -plastic or cardboard rings.
Frisbees and Friends Prediction Sheet

Which Object Will Sail Farthest?

Place an X next to the name of the object that you predict will sail the farthest.

______ Pie plate        ____ Paper plate
______ Frisbee          ____ Whoosh
______ Aerobie          ____ Sqwish

Why do you think the one you selected will sail farthest?

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
Disk 3: Fashion a Fabric Frisbee

Today's Frisbee takes its name from Frisbie Pie, the company that packaged its popular pies in a tin plate that sailed easily. Try sewing a fabric version of one of America's favorite flying objects.

**Gather these materials:**

- \(\frac{1}{6}\) yd. (13 cm) sturdy fabric (cotton/polyester or 100 percent cotton works well)
- Scissors
- 22-in. (56 cm) single-fold bias tape (circle circumference + 4 in. [10 cm])
- Tape measure or ruler
- Iron and ironing board
- 20-in. (51 cm) length drapery weight tape (circle circumference + 2 in. [5 cm])
- Sewing machine with zipper foot
- Needles and thread
- Straight pins

**Allow enough time:**

- 1 \(\frac{1}{2}\) to 2 hours
- Allow more time if sewing machines are shared or if sewers are inexperienced.

---

**Try it:**

1. Fold fabric and cut two circles of fabric of 5- to 6-in. (13 to 15 cm) diameter.

2. Cut bias tape to desired length (circle circumference + 4 in. [10 cm]). Press tape open, then fold in half lengthwise.
3. Cut weight tape to desired length (circle circumference + 2 in. [5 cm]).

4. Use zipper foot on sewing machine to stitch weight tape inside bias tape, along all edges, positioning weights along fold line of bias tape. Fold weighted bias tape lengthwise so raw edges are together.

5. Match raw edges of weighted bias tape with raw edge of the right side of one fabric circle. Carefully stitch through fabric circle and two layers of bias tape, easing tape into position.

6. Pin both circles together with right sides facing. Stitch through fabric circles and tape, leaving 2-in. (5 cm) opening for turning. Be sure to backstitch when you begin and finish stitching and to stitch inside previous stitching so that sewing does not show on right side.
7. Turn Frisbee right side out. Press, turning in seam along opening.

8. Hand sew opening closed.

Try sailing your fabric saucer.

**Don't stop now:**
- Personalize your Frisbee with lace, ribbons, or fabric paints.
- Compare the performance of this handcrafted item to that of the commercial product.
- Design a game with your new fabric Frisbee. One idea is a variation of ring toss. Place three sizes of containers (hoops, boxes, buckets, or baskets) on the floor in a row, from largest to smallest. The largest container should be near the thrower and nets the smallest score. The smallest container is far from the thrower and nets the largest score. Try to sail your fabric Frisbee into the containers.
- Make fabric Frisbees for a children's center or hospital as a community project.

**Let's talk—and think—about what happened:**
- Did you find it difficult to sew along the curved edge? What successful strategies did you discover for fitting the curves?
- What is the role of the bias tape? Could you use any narrow length of fabric to bind your Frisbee? (Bias tape is a fabric strip cut at a 45-degree diagonal to provide flexibility. It is used to bind, face, or pipe curved edges. It can be purchased single- or double-fold.)
- This Frisbee is a smaller, softer object than most commercial products. List two advantages and two disadvantages of these characteristics.

**Tips for leaders:**
- Test sewing machines before the activity.
- Enlist helpers if sewers are inexperienced.
- Provide washable fabrics so Frisbees can be easily cleaned.
- Provide different prints or patterns so that each Frisbee is personalized.
The term airplane was introduced during the nineteenth century to describe a powered flying machine with a fixed plane surface for wings. In 1903, Orville and Wilbur Wright flew such a machine in the first sustained, controlled, and piloted flight. Their airplane, the Flyer, traveled 120 feet (36 m) in 12 seconds. It was constructed of wood, metal, chains, and wires; its wings were covered in cotton fabric. From this exciting but limited beginning grew the airplane industry and a timeless relationship between airplanes and fabrics.

As an airplane picks up speed on a runway, its wings meet the oncoming air. Air moves under the relatively flat bottom surface of the wing, pressing the wing upward. Air also flows over the curved top surface of the wing, but this is a long path. To compensate for the added distance, the airflow speeds up over the upper surface, becoming less dense and thereby exerting less pressure on the top surface of the wing. The difference between the pressure on the upper and lower surfaces forces the airfoil upward (lift). Lift can be increased or decreased to some extent by changing the angle at which the airfoil meets the air (Unit 1: Principles of Flight and Heavier-Than-Air Flight).

For the airplane to move forward, it must overcome drag. Its size, shape, method of propulsion, and aerodynamic design determine how easily this is accomplished (Unit 1: Aerodynamic Design).

Once the plane is airborne, control becomes vital. Modeled after fish and birds, airplanes are equipped with nonmovable fins and movable wing parts to keep the plane in the air and on course.
**TERMS**

**Aileron** Movable airfoil near trailing edge of an airplane wing that helps control plane movement

**Biplane** Airplane with two sets of wings, one above the other

**Elevator** Movable airfoil on trailing edge of horizontal stabilizer that controls up and down movements and pitching

**Horizontal stabilizer** Horizontal structure at rear of plane that keeps plane on course

**Landing gear** System for airplane support or mobility on land or water. Includes wheels, pontoons, and shock absorbers.

**Monoplane** Airplane or glider with only one pair of wings

**Propeller** Rotating blades that create a backward thrust of air, which helps to propel the craft forward

**Rudder** Movable piece attached to the vertical fin for controlling direction to left or right

**Vertical fin** Upright structure at rear of plane that aids stability
Airplane 1: Bernoulli’s Principle

In 1738, Swiss scientist Daniel Bernoulli published Hydrodynamic Principia, in which he noted that as the speed of a fluid or gas increases, the barometric pressure of the area it occupies decreases. This means that if an object experiences low pressure above and high pressure below, it will be lifted upward. This also means that some objects can fly—and that we can have fun testing Bernoulli’s principle.

Gather these materials:
- Hair dryer
- Ping-Pong balls (one for every 2 students)

Allow enough time:
- About 15 minutes

Try it:
1. Turn on hair dryer and point it upward.
2. Release Ping-Pong ball in airstream about 5 in. (15 cm) above hair dryer nozzle.
3. Slowly move hair dryer up and down and left and right.

Don’t stop now:
- Try balloons and light beach balls.
- Direct the short spout of a bendable plastic straw upward. Hold the Ping-Pong ball over the spout and blow very hard into the other end of the straw. As you feel the air around the ball, let go of the ball and it will be trapped in the airstream—until your lungs surrender.

Let’s talk—and think—about what happened:
- Why does the Ping-Pong ball remain in the airstream?
- What happened when you moved the hair dryer?

Tips for leaders:
- Use no more than two hair dryers on one electrical circuit.
- Provide each participant with his or her own straw.
- Some tank-type vacuum cleaners can be used instead of the hair dryer. Attach the hose to the blower rather than to the suction end.
- Refer to the Lift section in Unit 1: Principles of Flight.
- Refer to the Streamlining section in Unit 1: Aerodynamic Design.
Thanks to the special shape of an airfoil, flying crafts are possible. Thanks to Bernoulli's principle, we can understand why they are possible. Let's make a simple airfoil and see why this shape is perfect for airplane wings.

**Gather these materials:**
- Piece of paper (8 1/2 in. [21.5 cm] square works well)
- Cellophane tape

**Allow enough time:**
- 15 minutes

---

**Try it:**

1. Fold paper diagonally, leaving 1 in. (2.5 cm) space along edges.

```
\[\text{Fold Line #1}\]
```

2. Fold bottom edge up about 1 in (2.5 cm).

```
\[\text{Fold Line #2}\]
```

---

104 Fabric/Flight Connection: Unit 1. Things That Fly
3. Bring outside points of base together, tucking one inside the other.
   Tape in place.

4. Grasp airfoil at the apex—point farthest away from folded base.
   Hold over your head and throw as if throwing a baseball overhanded.

---

**Don't stop now:**
- Try throwing the airfoil underhanded as in a softball pitch.
- Try larger pieces of paper.
- Draw an airplane that has its wings curved upward and joined together.

**Let's talk—and think—about what happened:**
- Why does this simple structure fly so easily?
- Compare the shape of this airfoil to the shape of an airplane wing.
- Which side of the airfoil was in the downward position?
- Can you imagine an airplane with its wings curved overhead? Why would that design—the ring-wing aircraft—use less fuel?

---

**Tips for leaders:**
- The side of the paper airfoil that has the apex is heavier than the opposite side and is kept in the downward direction by gravity, which stabilizes its flight.
- Participants may need a few practice tosses—too much or too little speed or a lack of follow-through may affect the flight.
- Ring-wing aircraft have been investigated for possible use after the year 2000. Because the wingtips are circular, the wing structures are strengthened and use less materials. Lower weight means greater fuel efficiency.
- Refer to the Lift section in Unit 1: Principles of Flight.
- Refer to the Streamlining section in Unit 1: Aerodynamic Design.
Airplane 3: Shape Up

The broad wings of an eagle are built for soaring. The short, rounded wings of a wren are engineered for quick maneuvers in tight places. The Stealth bomber is one continuous wing—a shape that helps it slip through radar unseen. Different wing and airplane shapes are needed for different purposes. Let's start with a familiar T-shaped airplane and then experiment with different shapes.

**Try it:**

1. Photocopy or trace pattern and cut out.
2. Fold paper in half lengthwise. Place pattern along fold and trace outline with pencil.

3. Cut along penciled lines.

---

**Gather these materials:**
- Tracing paper
- Airplane pattern (p. 108)
- Scissors
- Construction or other stiff paper (1 sheet per plane)
- Pencil
- Glue

**Allow enough time:**
30 to 45 minutes
4. Place glue along fold line. Press body and nose of airplane together. Allow glue to dry.

5. Spread wings and tail fins. Test your plane.

**Don't stop now:**
- This plane is shaped like the letter T. Try making a plane in the shape of one of your initials. If your initial is not symmetrical like a T or Y, use your initial and its mirror image. For example, if your name is Carol, place two Cs back-to-back like this: ☹.
- Try attaching the wing at a different point along the plane body. For example, change the T shape to a + shape or invert it ↓ by moving the horizontal wing line to the middle and bottom of the vertical line.
- Create a shape based on something you have seen in nature and see if it will fly.
- Plan a field trip to a museum or nature center to explore wing shapes in nature.

**Let's talk—and think—about what happened:**
- How did the shape of the airplane affect its flight?
- Have you observed the different wing shapes of birds and insects? If not, check an encyclopedia, nature magazines, or books to learn which shapes are best for gliding and for quick movements.
- Does the placement of the wing along the body of the plane affect its flight?

**Tips for leaders:**
- If sufficient supervision is available, you might allow participants to launch their planes from a balcony or high window. This extra space and recovery time provides some interesting observations.
- Wide wings provide lift to support more weight.
Airplane 3: Shape Up Pattern

PLACE ON FOLD

1/2"

4"

1 1/8"

2 5/8"

3/4"

1 1/2"
Airplanes must be steered to the left and right and up and down. This requires stability and control, which is provided by control surfaces. Flaps are the control surface on the trailing edge of an aircraft wing. They are used to increase lift or drag. Flaps on the horizontal stabilizer of the tail are called elevators or tail flaps. Try making this airplane to learn how tail flaps work.

**Gather these materials:**
- Airplane pattern (p. 112)
- Tracing paper
- Paper (1 sheet per airplane)
- Pencil
- Scissors

**Allow enough time:**
30 to 45 minutes

---

**Try it:**

1. Photocopy or trace pattern and cut out.

2. Cut a sheet of paper so it is 8 in. (20.5 cm) wide x 8 1/2 in. (21.5 cm) long.
3. Starting on one side, fold in \( \frac{1}{2} \) in. (1.5 cm), then fold four more times. Fold paper in half from bottom to top.

4. Draw a line across paper 1 in. (2.5 cm) from bottom fold. Crease each half of paper outward along line.

5. Lay pattern along crease and outline in pencil.
6. Cut through both layers along pencil line.
7. Open plane by flattening each half of paper along crease. For flaps, cut a slit \( \frac{1}{2} \)-in. (1.5 cm) deep and 1 \( \frac{1}{4} \) in. (3 cm) from outer edge of each side of tail.

8. Test model to see if it flies straight.
9. Bend tail flaps down and observe flight.
10. Bend tail flaps up and observe flight.
11. Bend one flap up and one flap down and observe flight.

Don't stop now:
- Make a new pattern with larger flaps and repeat the flying sequence.
- Examine model planes and magazine photos to see how flaps are used.
- Visit an airport to watch planes take off and land. Try to observe the flaps or other control surfaces working.

Let's talk—and think—about what happened:
- What was the effect of the tail flaps and their position on the airplane's flight?
- Was the size of the tail flaps important?
- How should you position the flaps in preparation for landing an airplane?

Tips for leaders:
- When flaps bend downward, the tail moves up and the plane noses down.
- When flaps bend upward, the tail moves down and the plane climbs.
Airplane 4: Tail Flaps Pattern

PLACE ON FOLD

TAIL

WING
If you were given two strips of paper and one drinking straw, could you design an airplane that would fly? Think about the principles of flight and aerodynamic design as we try it.

**Gather these materials:**
- 1 strip of paper $\frac{1}{2}$ in. $\times$ 3 $\frac{1}{2}$ in. (1.5 cm $\times$ 9 cm) long
- 1 strip of paper $\frac{3}{4}$ in. $\times$ 4 $\frac{3}{4}$ in. (2 cm $\times$ 12 cm long)
- 1 plastic straw
- Cellophane tape

**Allow enough time:**
- 15 to 30 minutes

**Try it:**
1. Make a loop out of each strip of paper, overlapping ends and taping them inside and outside loop to form a pocket.
2. Put one loop on each end of straw by slipping straw through pockets.
3. Sail straw plane with larger loop pointed forward.
4. Sail it with smaller loop pointed forward.

**Don't stop now:**
- Experiment with the loops in different positions along the straw.
- Try plugging one end of the straw. Does that make a difference in the plane's flight?

**Let's talk—and think—about what happened:**
- Did you expect this plane to fly? Why or why not?
- Did the straw plane fly best with the small or large loop pointed forward?
- Into what positions did you move the loops?
- How did these positions affect flight?
- Where is the center of gravity of this plane?
- What happened when you plugged one end of the straw?

**Tips for leaders:**
- Discourage the use of too much tape because it can add weight.
- The paper rings are shaped like airfoils and thus follow Bernoulli's principle for lift.
Helicopters

The helicopter is the most versatile aircraft. It needs no runway to take off or land. It can fly up and down, forward and backward, and even hover in the same spot. The helicopter is an able warrior in military conflicts, an honored hero in medical evacuations, and a dependable commuter craft.

Always intrigued by winged flight, Englishman Sir George Cayley built a small helicopter out of feathers, corks, whalebone, and string in 1796. A French version used silk-covered wire frames. Both inventions could rise from floor to ceiling and became popular toys of the period.

The principles discovered by Cayley were put into practice in 1907 by Frenchman Paul Cornu, who designed and flew the first helicopter. The craft rose only 6 feet (1.8 m) and stayed aloft for 20 seconds. The first stable craft with rotating wings was the autogiro flown by Juan de la Cierva in Spain in 1923. His aim was the safer flight provided by a rotary-wing aircraft, not the maneuverability of today's helicopters. Germans Heinrich Focke and Anton Flettner designed a helicopter in 1937 using two rotors that turned in opposite directions, like two beaters on a hand mixer. The major breakthrough in helicopter design was Igor Sikorsky's 1939 model, which had variable-pitch rotor blades and a small tail rotor.

The rotors, or spinning blades, act as wings and propellers, providing both lift and thrust. As the rotor blades spin around, they push air down.

This compressed air under the rotors pushes the helicopter upward (thrust), and the blades act as airfoils to create lift.

Helicopters have two sets of rotors. The larger one sits on top of the body and is the main rotor. The smaller one is at the rear of the craft and is called the tail rotor. The main rotor provides thrust and lift and controls the direction of flight through blade angle. The tail rotor provides balance and steering. Without the tail rotor, the torque forces of the main rotor would spin the helicopter in the opposite direction of rotor spin.

Each rotor blade is connected to a flying hinge that drives the blades. The hinge allows the blades to flap, balancing the lift and preventing rollovers. Pitch or wing angle is controlled by the swash plate, which tilts and moves up or down.
Helicopter I: Nature’s Whirlybirds

Mechanical helicopters have existed for more than 50 years, but nature’s helicopters have existed for eons. One natural helicopter is the maple seed, whose asymmetric geometry causes it to rotate as it falls. In this activity, you will model a maple seed and understand how it behaves like a propeller wing.

Gather these materials:
- Maple seed pattern (below)
- Tracing paper (optional)
- Pieces of paper or cereal boxes at least 4 in. square (10 cm)
- Pen or pencil
- Scissors
- Paper clips

Allow enough time:
- 15 to 30 minutes

Try it:
1. Photocopy or trace patterns and cut out maple seeds.

MAPLE SEED

PATTERNS (ACTUAL SIZE)
2. Attach a paper clip to each design and warp paper slightly to produce airfoil shape.

3. Drop each “maple seed” from at least 5 feet (1.5 m) and watch it fall.
4. If maple seed fails to rotate, adjust position of paper clip slightly.

Don’t stop now:
- Experiment with different designs of your own making.
- Try folding the wing at different angles and see how this affects the fall.

Let’s talk—and think—about what happened:
- Why is it important for maple seeds to rotate?
- What do you think you were adjusting when you moved the paper clip for successful rotation?
- Where do you think the center of mass is for the paper maple seed model?

Tips for leaders:
- Maple seeds are superb natural helicopters. Even seeds that are poorly shaped or badly damaged begin rotating as soon as they are released from the tree.
- The maple seed rotates because it is asymmetrical. The seed’s center of mass is shifted to one end, whereas its center of lift is approximately in the middle. As the seed falls, it rotates in a circular motion that inscribes a cone around the axis of fall. The shape of the cone varies with the aerodynamic qualities of the seed’s blade (wing). A blade that has minimal lift properties will inscribe a steep-sided cone, whereas a blade with strong lift properties will inscribe a flattened cone.
Helicopter 2: Paper Chopper

A paper helicopter demonstrates the same principles of flight as the maple seed, except that it has two propellers instead of one. By changing the angle of the wings, the helicopter will fall at different rates and angles.

**Gather these materials:**
- Paper
- Helicopter model (p. 120)
- Scissors
- Tracing paper (optional)
- Pen or pencil (optional)

**Allow enough time:**
- 15 minutes

**Try it:**
1. Photocopy or trace pattern and cut out model.
2. Cut along dotted lines.
3. Fold A inward along solid line. Fold B inward along solid line over A.
4. Make three \( \frac{1}{4} \)-in. (6 mm) folds at the bottom of A and B.

5. Fold C and D in opposite directions to form blades.

*Drop helicopter from a height and watch it rotate.*

**Don’t stop now:**
- Change the angle of the propeller blades, and notice the difference in how the helicopter falls. Can you make the model move left or right by changing the blade angle?
- Draw a circle of any size on the floor or pavement with chalk and try to land your model in the space.

**Let’s talk—and think—about what happened:**
- In what direction does the rotation occur? Can the helicopter ever rotate in the opposite direction?
- Why did changing the wing angle change the fall and direction of the helicopter?
- What two forces are acting on the blades?
- What other objects show a spin similar to that of helicopters and maple seeds?

**Tips for leaders:**
- Gravity pulls the helicopter down, but the rotation of the blades provides lift.
- In general, larger helicopters rotate better than smaller ones, and lightweight paper is better than heavy paper.
- Be sure that small children are supervised when dropping the helicopters from any height.
- This is a great demonstration activity for a fair or the classroom.
- When working with small children, use larger circles when trying to land the model.
Helicopter 2: Paper Chopper Pattern

Photocopy page. Cut out six patterns.
Humans have long had the ambition and courage to fly, but their early efforts were thwarted because they lacked the appropriate materials. As the ability to create and manipulate fibers has expanded, so has the horizon of aviation. An amazing array of fibrous materials is available for the modern flier's craft and clothing.
Fibers: The Foundation of Flight

Fibers are the building blocks of textiles. They are obtained from plants, animals, and minerals or manufactured from chemicals. They are composed of cellulose, protein, inorganic compounds, or petroleum derivatives. Fibers are laid, twisted, or knotted together to form yarns that are woven, knitted, or bonded into fabrics. Fibrous elements are also embedded in binding materials to create composites. The role of fibrous materials in aviation is historical and functional and has yet to reach its full potential as new fibers, fabrics, and composites await exploration.

Natural Cellulosic Fibers

Staple plant fibers such as bark, cotton, and linen are composed of polymers formed from glucose. They are moderately strong, combustible, and inflexible. The Chinese used cellulosics in their early kites, and eighteenth-century Europeans constructed hot air balloons from paper and covered early blimps and rigid airships with woven cotton cloth. The Wright brothers also chose cotton fabric to cover the wings of the Flyer, the airplane they used in the first powered flight. Cotton has always been popular for aviator clothing and has been used by NASA since 1978, when flame-resistant cotton garments were introduced to agency astronauts, test pilots, and ground crews.

Silk

This protein fiber, composed of amino acid polymers, is the only naturally occurring textile filament. It is moderately strong, absorbent, and sensitive to acids, alkalis, and ultraviolet light. Commercially available silk comes from the larva of the silkworm and has been used in hot air balloons and in parachutes. In 1990, a genetic scientist discovered a way to mass-produce spider silk that is 5 to 10 times stronger than a steel wire of similar diameter. Future uses of this tough material might include parachute cording, sleeping bags, and clothing.

TERMS

Fabric Material constructed from yarns by weaving, knitting, braiding, knotting, netting, or fusing
Fiber Slender strand of material suitable for making textiles
Filament Fiber that is longer than 18 in. (45.5 cm)
Finish Special process or chemicals applied to fibers, yarns, or fabrics to extend their usefulness. Examples are ultraviolet-resistant, water-repellent, or flame-retardant finishes.
Knitted fabric Fabric made by interlocking one loop of yarn into another
Manufactured fiber Fiber obtained through a manufacturing process using natural or synthetic raw materials that may or may not be fibrous
Natural fiber Fiber readily obtained in fibrous form from plants, animals, or minerals
Nonwoven fabric Webs of fiber held together through interlocking scales as in felted wool or through bonding owing to heat, chemicals, or pressure
Polymer A large compound made of many small repeating units
Staple Fiber that is 18 in. (45.5 cm) or less in length
Synthetic fiber Fiber obtained through a manufacturing process using petroleum derivatives
Textile Planar structure consisting of fibers or yarns
Woven fabric Fabric made by interlacing yarns at right angles
Yarn Continuous length of staple fibers, filaments, or other materials suitable for making textiles
Wool
A natural protein fiber from the fleece or hair of animals, wool is durable, elastic, absorbent, and flame resistant. It is made into carpet, upholstery, curtains, and wall coverings for aircraft interiors. Wool fabric treated with low-smoke finishes (smolders rather than burns) is also popular in blankets and uniforms used aboard aircraft.

Rubber
This fiber is made from natural or synthetic substances. It is characterized by its elasticity, water repellence, and electrical resistance. Natural rubber is obtained from a plant fluid called latex and was known to the natives of South America long before the Europeans arrived there. Synthetic rubbers such as isoprene, neoprene, and butyl are produced from unsaturated hydrocarbons. They were developed from work done by Charles Williams in 1860 but were not generally available until the 1930s and 1940s. Rubber was used to coat the cotton fabric of the great rigid dirigibles like the Los Angeles and the Hindenburg. It is also found in radios, insulation, tires, belts, hoses, balloons, and protective clothing.

Rayon
Rayon, which is manufactured from regenerated cellulose (wood pulp), became available in the 1920s. It is absorbent, dyes easily, and resists ultraviolet light. Less strong than other fibers, rayon has been less popular in flight applications. Carbonized rayon, engineered for fire resistance, is used in the solid rocket booster nozzles of the space shuttle.

Nylon
Nylon is a long chain of amide groups. Synthesized from petroleum derivatives in the 1930s, it was the first manufactured noncellulosic fiber. Nylon revolutionized many areas of the flight industry because it is lightweight, nonabsorbent, and resists tears and abrasion. Nylon is used in many parachutes, kites, hang gliders, and hot air balloons as well as for accessories such as ropes, straps, kite line, and garments.

Polyester
This long-chain polymer is composed of ester units. First produced in the 1950s, polyester is almost as strong as nylon and has better resistance to sunlight. Thus polyester is used in structures such as blimps and stunt airplanes that remain airborne for long periods of time. Polyester films such as Mylar are also used for kites and sails.

Olefin fibers
Polypropylene and polyethylene swept onto the scene in the 1950s. These fibers are resistant to many chemicals, moisture, and insects but are sensitive to heat and sunlight. Polypropylene—of Astroturf fame—is used in garments for fliers because it is able to wick, or transport moisture away from the skin without the garment becoming wet. Tyvek, a nonwoven polyethylene fabric, was introduced in 1968 and is used today in hobby kites and protective garments. Spectra, a polyethylene fiber of ultra-high strength and ultra-low weight, was introduced in 1985. It is used in aviation for tethers, cables, suspension lines, balloon and parasail fabric, parachutes, and cut-resistant clothing.
Carbon/graphite
Carbon and graphite fibers are made by heating a rayon or acrylic filament or petroleum residues to between 1500°C (2740°F) and 2500°C (4566°F) and converting it to 95 to 99 percent carbon. The term graphite is reserved for 99 percent carbon fibers, which are strong and heat resistant. Available since 1959, they are used in rotor blades for helicopters, compressor blades in jet engines, and in the construction of space vehicles.

Aramid fibers
In 1974 the Federal Trade Commission established a generic classification for aramids, a family of polyamide fibers. Aramid fibers—Kevlar and Nomex—have outstanding strength-to-weight properties, high breaking strength, and low flammability. Kevlar is famous for its use in bulletproof vests but is also used for parasails and towline. Nomex is important for protective clothing such as the space suit but was also used in the Gulfstream IV, an executive jet aircraft. Both Kevlar and Nomex are components of a thin (only 0.095 in. or 0.24 cm in diameter) cable that tethers a 1,200-pound (545 kg) research satellite to its parent space shuttle.

Ceramic fibers
These fibers are made of aluminum silicate. Because they are light and strong, they are popular for rotor blades and as reinforcements for plastics. Because they can withstand temperatures of 1832°F (1000°C), they have been used as gaskets between space shuttle tiles, as fire protection for wire harnesses in military aircraft, and as flexible insulation in tail cones and pipes of jet engines.

Composites
A composite is an article or substance made of two or more compatible parts. The most common structure is a matrix binder reinforced by fibers or fabric. The matrix provides support and protection; the fibrous component adds strength and flexibility. Common matrices are plastic and epoxy; popular fiber components are glass, graphite, aramids, and olefins. Wood is a natural composite of cellulose fibers in a matrix of lignin. The first manufactured composite was fiberglass—glass fibers in a plastic matrix. Another familiar composite is the cast that physicians use to set a broken bone. The gauze is the fiber component; the plaster is the matrix.

Composites are increasingly used in aviation because they are stronger, lighter in weight, and more moldable than the metals commonly found in aircraft. First used in military aircraft, composites are seen today in the F-16 fighters used by the Air Force’s Thunderbirds, the Grumman X-29, and the AV-8B, a vertical takeoff and landing craft. The remote manipulator arm of the space shuttle uses composites as does the Boeing 777 airplane. The Voyager aircraft, which circled the globe in nine days in 1986 without refueling, was made entirely of composites.
**Material Properties**

The performance of a material depends on its properties. Textile properties important in aviation are air permeability, durability, flammability, insulative ability, moisture response, and weight. Materials that have the ideal combination of these properties are rare. Each decision about material use is a compromise between what is needed and what textiles can deliver.

**Air permeability**

The degree to which air can penetrate fabrics is important to flight and to the maintenance of the fabrics used in flight. The four principal ways to control permeability are through yarn construction, fabric construction, layering, and finishes. Fabrics made from closely woven, fine yarns provide greater resistance to air penetration than loosely woven fabrics or fabrics made from softly spun yarn. Fabrics can be layered or treated with finishes to reduce permeability.

**Durability**

Durability is the ability of a fabric to retain its physical integrity under stress. Durability encompasses strength, abrasion resistance, elongation, elasticity, and flexibility.

**Strength**

This characteristic of a fabric depends on three features:

- Breaking strength = withstands longitudinal pull
- Tearing strength = resists lateral tears at a cut or hole
- Bursting strength = resists punctures

Textiles for flight must be durable enough to withstand the elements, support the flying structure, and protect the fliers.

**Abrasion resistance**

This is the ability of a fabric to withstand a frictional force such as rubbing. Some common textile fibers, listed in order of their resistance to abrasion, are nylon, polyester, acrylic, wool, cotton, and rayon. Abrasion resistance also depends on the yarn twist and size and on the fabric structure and finish.

**Elongation**

Elongation is the ability of a yarn or fabric to extend before breaking. All fibers and yarns have some ability to elongate, otherwise they could not tolerate the fabric manufacturing process. A high degree of elongation is desirable to prevent rupture, but a low degree of elongation is required to prevent shape from changing. Elongation is related to textile stiffness, strength, and elasticity.

**Elasticity or elastic recovery**

This is the ability of a yarn or fabric to stretch and then return to its original shape. It depends on the elasticity of the fibers and the structure of the cloth. Spandex and rubber exhibit excellent elasticity and are known as elastomers. Nylon and polyester have good elasticity, silk and polypropylene have medium elasticity, and cotton has poor elasticity. Knit fabrics should stretch about 15 percent; common woven fabrics...
only 2 to 3 percent. Power stretch fabrics such as surgical support hose combine elastomeric fibers with knitted structure to permit extension up to 200 percent.

**Flexibility**

Flexibility, the ability to bend without breaking, depends on the stiffness of the fibers, the twist of the yarn, the structure of the fabric, and the pliability of finishes. Flexible materials can be manipulated to create an aerodynamic shape and can accommodate stress changes. Because the nylon parachute is flexible, it can expand when filled with air and be folded to fit for compact storage.

**Flammability**

Flammability describes the ease of ignition and the speed and length of time that a fabric burns. Flammability depends on the chemical composition of the fiber, the construction of the fabric, and the combustibility of dyes and finishes. Thus cotton burns, nylon melts, and aramid fibers are inherently flame retardant. Flame-retardant chemicals are added to fibers such as nylon, rayon, and polyester during manufacture; they are applied to the surface of yarns and fabrics of cotton, wool, polyester, and nylon.

**Insulative Ability**

Insulative ability is defined as the resistance to heat transfer. Heat is transferred from warm to less warm objects. The rate of movement depends on the difference in temperatures of the two objects and on the insulative ability of each. Textile fibers resist heat loss. They are 1,000 times less conductive than aluminum. Fabrics are even more resistant to heat flow than are fibers because the interlacing of fibers and yarns creates insulative spaces of air. Thus fabrics are good insulators against the cold and provide protection from the sun. The degree of insulative ability depends on the fiber content, yarn, and fabric construction.

**Moisture Response**

Fibers respond to water in many ways. They hold water inside (absorb), on the surface (adsorb), and in the fabric interstices (imbibe). They transport water by wicking, or capillary action, in both the horizontal and vertical directions. They also release water through evaporation. Cotton, wool, and rayon are comfortable to wear because they hold moisture to cool the body. In contrast, nylon or polyester release water for quick drying. Tightly woven fabrics resist moisture penetration. Yarns and fabrics can be treated with chemical finishes to increase their resistance to water. Water-repellent finishes are not waterproof. Large amounts of water or water that falls forcefully can eventually penetrate the fabric. Some finishes allow small water vapor particles to pass through, while blocking larger liquid water droplets.

**Weight**

Fabric weight depends on the density, thickness, number, and twist of the yarns used to make the fabric. Fibers of high density (glass or asbestos) make heavy fabrics; low-density fibers (silk or nylon) make lightweight fabrics. Lightweight textiles are usually preferred for aviation purposes.
Have you ever strung beads together to make a necklace? Has anyone in your group ever built a snowman from marshmallows and toothpicks? In each of these examples, individual units were combined to make another, larger item. You might think of the beads and marshmallows as monomers, which when put together formed a polymer. Nature makes many polymers, including starch, cellulose, rubber, and silk. Polymers such as nylon, plastics, and Teflon are made in a laboratory or factory. All textile fibers are polymers. Let's make a polymer and explore what it can do.

**Gather these materials:**
- Newspapers
- Paper towels
- Elmer's white glue
- Small paper or plastic cups
- Set of measuring spoons
- Epsom salt
- Water
- Wax paper
- Ruler

**Allow enough time:**
20 to 30 minutes

**Try it:**

1. Cover work surface with newspaper and a double layer of paper towels.

2. Place 1 tbsp. (15 ml) glue in small cup.

3. Place 1/2 tsp. (1.5 g) Epsom salt and 1/2 tsp. (2.5 ml) water in a separate cup. Swirl to dissolve salt (some salt may remain in bottom of cup). Pour dissolved Epsom salt into glue cup and stir.
4. Scoop mixture onto paper towels. Fold towels over mixture and press down to absorb extra water. The resulting material is a polymer called plastic.

5. Form plastic into as long a roll as you can without breaking it. Measure length of roll.

6. Form plastic into a ball and press it down on a piece of wax paper to make the biggest pancake you can. Measure diameter.

7. Form plastic back into a ball and try bouncing it.

**Don't stop now:**
- Review *The Fabric/Flight Connection* videotape, part II, which introduces polymer science (Unit 4: Sources for Educational Materials, Cornell University).

- Visit your library or check out the Internet for references on plastics. List different names for plastics (polyethylene, polyvinyl chloride, polypropylene).

- List ways in which plastics are used in aviation and in everyday life. Energize the list-making by tossing an inflated balloon around. The person with the balloon has to state a use of plastics.

**Let's talk—and think—about what happened:**
- Describe how the plastic behaved when you stretched, flattened, and bounced it.

- Can you think of everyday situations when you need materials that can be stretched, reshaped, or dropped without being broken?

**Tips for leaders:**
- Provide plenty of paper towels or old cloth towels to absorb the water.
What do parachutes, socks, airplane tires, and the space shuttle have in common? All can trace their heritage to fibers. All textile fibers are polymers, but they come to us from plants, animals, and factories. They have different characteristics because of their different atoms and molecules and because of the different ways these atoms and molecules are connected. Some of these characteristics can be observed by handling the fibers; others can be seen by using a magnifying lens. Some are revealed only through tests and use. Let's look at some fibers and see how many characteristics we can observe and how those characteristics change when fibers are combined to make yarns.

**Gather these materials:**
- Cotton (sheet of rolled cotton, quilt batting)
- Ruler
- Masking tape
- Black construction paper
- Pencil
- Polyester (Dacron quilt batting)
- Wool (fleece or lamb's wool from foot-care area of drugstore)
- Magnifying lens
- Log-in chart (p. 132)
- Yarns (string, twine, fishing line, rope, mop heads, sewing thread, knitting yarn, and weaving yarns of different fibers, colors, and textures), cut in 8-in. (20.5 cm) lengths
- Microscope (optional)

**Allow enough time:**
- 30 to 45 minutes

**Try it:**
1. Twist cotton fibers to make yarn about 8 in. (20 cm) long and 1 in. (2.5 cm) wide.
2. Tape yarn to construction paper. Write “cotton” on the tape.
3. Repeat steps 1 and 2 with polyester and wool. Label the tapes “polyester” and “wool.”
4. Carefully separate one fiber from each yarn.
5. Examine fibers closely with the magnifying lens.
6. Rate the fibers as 1 (most), 2 (medium), or 3 (least) for length, thickness, softness, and crimp (wrinkles).

7. Record ratings on log-in chart, make an individual or group graph, or simply discuss your observations.

8. Make a blended yarn by twisting or rolling several fibers together.

9. Bend, stretch, and knot the cotton, polyester, wool, and blended yarns. Observe their behavior.

10. Select at least three commercial yarns. Pull them apart and separate one fiber from each. Compare these fibers with cotton, wool, and polyester fibers.

---

**Don't stop now:**

- Collect some fabrics. Try to pull yarn from these fabrics and then separate the fibers from the yarn. Compare these fibers to the cotton, wool, and polyester.

- Guess the fiber content of group members’ clothing. Then read the fiber content labels to confirm your guess.

- Visit a fabric or yarn shop. List all the fiber names you see in the store (cotton, acrylic, wool). List all the blends or combinations of fibers (cotton-polyester, nylon-wool).

---

**Let's talk—and think—about what happened:**

- Was it easy to separate the fibers from the yarn?

- Could you see any characteristics with the magnifying lens that you couldn’t see without it?

- Which fiber ranked as number 1 for length? thickness? softness? crimp?

- Could you bend, twist, and knot the cotton, wool, and polyester yarns?

- What other characteristics could you use to sort the fibers and yarns? (color, texture, odor)

- Could you guess whether the commercial yarns were from plants or animals or manufactured by comparing them with the cotton (plant), wool (animal), and polyester (manufactured) fibers?

---

**Tips for leaders:**

- Microscopes can make this experience more exciting.

  1. Clean lens, slide, and cover glass.

  2. Place a drop of water on the slide.

  3. Place a few fibers on the slide.

  4. Cover with cover glass and press down to eliminate air bubbles.

  5. Place slide on stage of microscope and focus using low power. If you have too many fibers or if they are not well separated, it will be difficult to focus on a single fiber.

- Introduce surprise fibrous materials such as human hair, milkweed floss, corn silk, feathers, or pineapple fibers (scrapped from the leaves).
### Log-in

**Fiber Explorations**

<table>
<thead>
<tr>
<th>Fiber Name</th>
<th>Length 1, 2, 3</th>
<th>Thickness 1, 2, 3</th>
<th>Softness 1, 2, 3</th>
<th>Crimp 1, 2, 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 = most  
2 = medium  
3 = least
You don’t have to be named Charlotte to appreciate the intricacy, beauty, and utility of a spiderweb. Spider silk is the strongest fiber in nature. The spider begins by spinning long threads outward from a central point. These radial strands anchor the web in place. Other strands are woven from radial to radial to make a flycatcher of silk. You’ve probably noticed that the spiderwebs you see outdoors are complicated and often symmetrical. The indoor webs or cobwebs are usually simple and irregular. Let’s try “spinning” web designs with different yarns and test their strength.

**Gather these materials:**
- Stationary supports such as chairs (weighted with books), trees, or climbing structures
- Balls of twine or yarn
- Nonbreakable items of different sizes and weights (suggestions: shoe, coat, book, ruler, sheet of paper)

**Allow enough time:**
- 30 minutes to 1 hour

---

**Try it:**
1. Select or, if necessary, arrange and weight several stationary supports.
2. Give a ball of yarn or twine to each participant.
3. Tie one end of the yarn to a support.
4. Carry yarn back and forth (randomly or in a set pattern) between supports to form a web horizontal to the ground.
5. Select two locations on the web: one that appears weak and one that appears strong.

6. Review items that will be placed on the web. Predict which ones can be supported by the two locations and which will break or fall through the web.

7. Place lightest item on the strong spot and then on the weak spot. Observe what happens.

8. Continue placing items of increasing weight on the strong and weak sites until the web breaks, collapses, or allows an item to slip through.

---

**Don’t stop now:**

- Divide the group into teams and ask each team to build a horizontal web. Note the similarities and differences between the different structures. Test web strength by stacking magazines (or other appropriate items) one by one until the web breaks or collapses.

- Construct a vertical spiderweb between two upright poles. Try to run through the web. An interesting—but time-consuming—variation is to construct and test the vertical web a few strands at a time. Stretch three strands between two trees. Run through the structure, breaking it. Replace those three strands and add three more. Run through the web again. Replace those six strands and add three more. Continue breaking and rebuilding the web until it is too strong to break. Count the number of yarns that were needed.

- Observe spiderwebs in nature and draw the different designs.

---

**Let’s talk—and think—about what happened:**

- Strong yarns make strong fabrics. Sometimes, however, many strands of a weak yarn produce stronger cloth than few strands of a strong yarn. Did you predict which areas of the web would support the various items?

- Can you think of strong fabrics that have many yarns (jeans, trampolines, kites) and strong fabrics that have few yarns (woven hammocks, fishnets)?

- If you built more than one web, describe how they differed in appearance. Could you have made a perfectly symmetrical web? Guess whether it would have been stronger or weaker than the web you made.

- If you made a vertical web, how many yarns were needed to stop the runner?

---

**Tips for leaders:**

Human Loom

Weaving is the interlacing of yarns to make fabric. Looms are the principal equipment used in fabric production. They come in many styles and provide a mechanism to raise and lower the warp yarns, allowing the weft yarns to be inserted at right angles by hand or via a shuttle. In this exercise, humans substitute for loom parts. The product is a simple plain weave.

Gather these materials:
- 10 participants to manipulate warp
- 1 participant to carry weft
- Warp ropes: 100 ft. (30.5 m), cut into 5 equal lengths of 20 ft. (6 m) each
- Weft rope: 100 ft. (30.5 m), coiled

Allow enough time:
- 20 minutes for one weaving (groups generally want to try again with different participants serving as the weft carrier)

Try it (see diagram):
1. Form 10 participants into two parallel lines (A and B) of five persons each. Participants should turn and face one another to make five pairs.
2. Give one length of warp to each pair. These participants act as loom harnesses to hold and lift the warp.
3. Give weft to participant 11. He or she acts as the shuttle to interlace weft through warp yarns.
4. All five participants in line A kneel and hold ends of their ropes at ground level. Participants in line B are numbered 1, 2, 3, 4, 5.
5. Leader calls out the word "even." Participants in line B with even numbers stand; those with odd numbers kneel.

6. Participant 11 pulls weft over odd-numbered warps and under even-numbered warps, placing weft as close to participants in line A as possible.

7. Leader calls out the word "odd." Participants in line B with odd numbers stand; those with even numbers kneel.

8. Participant 11 reverses direction, pulling weft over even-numbered warps and under odd-numbered warps.

9. Continue until all of the weft is used. You may need to stop occasionally and push the weft toward line A to create more space. Participant 11 may have to crawl through the last few passes.

10. When finished, pull weft and warp ropes close together to see the plain weave structure.
Don't stop now:
- Try to make another basic weave structure: twill.

Twill weave results when yarns float over two or more yarns and then under one or more yarns (instead of over and under only one yarn as in plain weave). Twill interlacing progresses to the left or right by a unit of one to produce the familiar diagonal ridges. Twill fabric is close in texture, heavy, and sturdy. The denim used in jeans is one example of a twill. To make a 2/1 twill (weft goes over two warp yarns and under one warp yarn), weave as above but substitute the following sequence of standing and kneeling for persons in line B:

<table>
<thead>
<tr>
<th>Persons in line B stand</th>
<th>Persons in line B kneel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1, 2, 4, 5</td>
</tr>
<tr>
<td>Pass weft</td>
<td></td>
</tr>
<tr>
<td>1 &amp; 4</td>
<td>2, 3, 5</td>
</tr>
<tr>
<td>Pass weft</td>
<td></td>
</tr>
<tr>
<td>2 &amp; 5</td>
<td>1, 3, 4</td>
</tr>
<tr>
<td>Repeat sequences</td>
<td></td>
</tr>
</tbody>
</table>

Let's talk—and think—about what happened:
- Because this exercise created a plain weave structure, every rope should alternate its position—over, under, over, under. Did you notice any mistakes? Did you know that intentional mistakes are sometimes used to create surface designs?
- Look at your clothing. Can you recognize a plain or twill weave?

Tips for leaders:
- The amount of rope can vary with the number of participants. The exercise is more fun with more people and longer ropes.
- The weave structure is easier to see if the warp and weft ropes are of different colors, sizes, or materials. For example, you might pair an undyed (beige) hemp rope with a yellow rope of polypropylene.
- The cut ends of the ropes should be wrapped with plastic or electrical tape to prevent fraying and to provide a comfortable grip.
- The leader might stop the weaving after each pass to pull the length of the weft tighter. This improves the visibility of the weave structure and allows for more passes of the weft.
Jeans and sweatshirts may be your favorite clothes, but did you know that the fabrics in these garments have different structures? You probably know which is woven (jeans) and which is knitted (sweatshirt). Can you describe each structure? Let’s look at some common fabric structures.

Gather these materials:
- Fabrics or articles of clothing that illustrate different fabric structures. Try hosiery (knit), lace (knotted or knit), handkerchief (woven), burlap (woven), hair net (netting or knit), and interfacing (nonwoven).
- Flashlight
- White paper or wall
- Magnifying lens

Allow enough time:
20 to 30 minutes

Try it:
1. Darken room and pull a fabric snugly over flashlight.
2. Shine light onto white object and note how much light passes through fabric.
3. Adjust angle of flashlight and distance from wall until you can see rough structure of fabric.
4. Move magnifying lens forward and backward between flashlight and wall until structure is in focus. Sketch or describe it.
5. Repeat procedure with other fabrics.
Don't stop now:
- Examine your clothing with a magnifying lens. Try to identify knitted and woven fabrics.
- Try making other fabric structures such as braided friendship bracelets, dream catchers, God's eyes, and cat's cradle.

Let's talk—and think—about what happened:
- Which fabrics are knitted and which are woven?
- Among the woven fabrics, which is most tightly constructed?
- Could you predict the structures of each fabric?

Tips for leaders:
- A magnifying lens with two levels of magnification adds interest.
- Try placing fabric on an overhead projector instead of over a flashlight.
Compose a Composite

What are strong, lightweight, and seen everywhere? The answer could be composites. Sailboats, tennis rackets, airplanes, and golf clubs are all made from composite materials—a fibrous material embedded in a binding material. Let's make two composites and test their strength.

Gather these materials:
- Plaster of paris
- Disposable plastic container
- Water
- Tablespoon measure
- Plastic teaspoon
- Shallow plastic lids from food containers, 3
- Cotton embroidery floss, ten 1/2-in. (1.5 cm) lengths
- Cotton gauze, one 1-in. (2.5 cm) length

Allow enough time:
1 hour (30 to 40 minutes for drying)

Try it:
1. Mix plaster of paris in container according to manufacturers’ directions. Add extra water (about 1 tsp. [5 ml] for every 6 tbsp. [54 g] of plaster) to make plaster easier to spread.
2. Place three shallow plastic lids open side up on a table.
3. Place about 2 tbsp. (18 g) of plaster in each lid and spread to cover evenly.
4. Place lengths of floss across plaster in one lid.
5. Place length of gauze across plaster in second lid.
6. Add second layer of plaster to all three lids, completely covering floss and gauze of first two lids.
7. Allow 30 to 40 minutes for plaster to dry.
8. Carefully remove plaster disks by bending lid edges away from plaster. If plaster starts to crack, allow more drying time.
9. Observe the three plaster disks. Do you note any differences?
10. Hold each disk with both hands and try to break in half. Note breakage patterns.
Don't stop now:

- Make masks from plaster of paris bandages available from school and art supply stores (Unit 4: Sources for Activity Supplies).
- Look up the composites fiberglass, wood, and honeycomb at the public library and report what you learned to the group.
- View The Fabric/Flight Connection videotape, part II (Unit 4: Sources for Educational Materials, Cornell University).
- View 3-2-1 Contact: Getting There (Unit 4: Sources for Educational Materials, NASA CORE).

Let's talk—and think—about what happened:

- Could you see any differences in the appearance of the three plasters?
- Which plaster was the most difficult to break?

Tips for leaders:

- Prepare an activity, use another activity from this book, or try one of the suggestions under “Don’t stop now” to engage the youth during the 30- to 40-minute wait for the plaster to harden.
- Read and follow the manufacturer's directions for mixing and disposing of the plaster.
- Do not mix too much plaster at one time. It may be easier to mix enough for each base layer (6 tbsp.) and a second batch for the top layer.
- Allow sufficient drying time.
**Air Permeability: It's a Breeze**

**Windjammer** is the name of a large sailing boat and a popular name for hot air balloons. It may sound poetic, but it has a functional meaning. The fabric used to make sails and balloons really does jam—block—the wind. Let's test the air permeability of some fabrics and look at ways to change that characteristic.

**Gather these materials:**
- Fabric squares large enough to fit embroidery hoops (2 pieces shirtweight cotton, 1 piece Tyvek, 1 piece ripstop nylon)
- Embroidery hoops
- Hair dryer
- Lightweight scarves
- Log-in chart (p. 144)
- Pencil

**Allow enough time:**
20 to 30 minutes

**Try it:**

1. Place one square of cotton fabric in an embroidery hoop.
2. Hold hoop and fabric upright with one hand. Hold hair dryer in other hand and direct air through fabric.
3. Ask a friend to test whether air is passing through fabric by holding his or her hand in front of it.
5. Log in air permeability rating.
6. Repeat using two layers of cotton cloth, one layer of Tyvek, and one layer of ripstop nylon.
Don’t stop now:
- Substitute handkerchiefs or small flags for the scarf.
- Try other fabrics you might have on hand and compare their performance with that of the four test fabrics.

Let’s talk—and think—about what happened:
- Did the air from the hair dryer pass through the fabric?
- Did the scarf move when you blew air from the hair dryer through the fabric? Describe how it moved.
- Compare the advantages and disadvantages of using fabric with a high degree of air permeability for a parachute.
- What about a windbreaker? Should it be made of fabric of low or high air permeability?
- How might you decrease the air permeability of a fabric?

Tips for leaders:
- Be careful not to plug too many hair dryers into the same circuit.
- Fans can be used to provide the “wind.”
- You may substitute other fabrics, but try to provide a range of air permeability.
- Tyvek sheets can be purchased at kite supply stores, Tyvek coveralls are sold in agriculture supply stores, and Tyvek envelopes are available at book, department, and office supply stores.
- For additional information about Tyvek, write to E. I. du Pont de Nemours & Co., Wilmington, DE 19898.
<table>
<thead>
<tr>
<th>Degree of Air Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

- **Single layer of cotton**
- **Double layer of cotton**
- **Tyvek**
- **Ripstop nylon**

1 = high permeability (most air passes through fabric)  
2 = medium permeability (average amount of air)  
3 = low permeability (least amount of air)
A stretch limousine means luxury. A stretched story is not quite true. Stretch pants are comfortable. The ability of a textile to stretch and then regain its original shape is called *elasticity* or elastic recovery. It depends on the construction of the cloth and the character of the fibers. Knit fabrics stretch more than woven fabrics. Rubber and spandex fibers (brand name Lycra) stretch more than other fibers and are called elastomers. They are used in balloons, active wear, bungee cords, and other products. This experiment compares the elongation and elasticity of some fabrics used to make hosiery.

**Gather these materials:**

- 4 knee-high stockings or socks of different fiber content.
- Allow one for each person if working in a group (see “Tips for leaders” for selection advice).
- Measuring tape or yardstick
- Log-in chart (p. 147)
- Pen or pencil
- Clothesline
- Clothespins or clamps
- 1 canned product (soup, vegetables, milk) for each stocking
- Stopwatch or watch with second hand

**Allow enough time:**

- 30 minutes to 1 hour

**Try it:**

1. Attach clothesline to walls or other supports.
2. Record original length (A) of stockings on log-in chart.
3. Secure them to clothesline with clothespins or clamps.
4. Predict which stocking will elongate most and which will recover best from stress.
5. Place one can of soup in each stocking. Wait 3 minutes.
6. Measure and log in extended length (B) of stockings.
7. Remove cans. Measure and log in final length (C) of stockings.
8. Calculate percent elongation of each stocking:

   \[
   \text{Percent Elongation} = \left( \frac{\text{Extended Length} - \text{Original Length}}{\text{Original Length}} \right) \times 100
   \]

**Example:** Original length = 10 in., Extended length = 12 in., Final length = 10.5 in.

\[
\text{Percent Elongation} = \left( \frac{12 - 10}{10} \right) \times 100 = 20 \text{ percent}
\]
9. Calculate percent elasticity or elastic recovery of each stocking:

\[
\text{Percent Elastic Recovery} = \frac{\text{Extended Length} - \text{Final Length}}{\text{Extended Length} - \text{Original Length}} \times 100
\]

Example: Original length = 10 in., Extended length = 12 in., Final length = 10.5 in.

\[
\text{Percent Elastic Recovery} = \frac{12 - 10.5}{12 - 10} \times 100 = 75 \text{ percent}
\]

---

**Don't stop now:**
- Repeat the experiment after wetting the stockings.

**Let's talk—and think—about what happened:**
- Which stocking showed the greatest elongation? the least?
- Which stocking showed the best elasticity?
- Did any of the stockings rip?
- Did you observe any difference when the stockings were wet?
- Can you think of ways that elastomers are used in your clothing? (athletic wear, waistbands, head bands, stretchy belts, turtlenecks)
- Investigate the history of natural and synthetic rubber.
- Visit a clothing store and list all the garments you find that contain spandex (brand name Lycra).

**Tips for leaders:**

When selecting stockings for this experiment, read the labels carefully and pretest their elasticity. Remember these points when you shop or raid your sock drawer:

- Power stretch fabrics stretch more than knit fabrics, which stretch more than woven fabrics.
- Elasticity ratings for some fabrics are:
  - Excellent: spandex and rubber
  - Good: nylon, polyester, and wool
  - Medium: silk, polypropylene, and acrylic
  - Poor: cotton, rayon, and acetate
- Even similarly rated fabrics may react differently. Both nylon and polyester exhibit good elasticity, but nylon is preferred for women's sheer hosiery because it recovers quickly from high stresses. Polyester is popular for other clothing because it recovers better from repeated low stresses.
- The greater the content of spandex, the greater the stretch of the fabric.
- Fabric stretch can change when a garment is wet. In general, protein fibers (wool, silk) stretch more when wet. Cellulosic fibers (cotton, linen) stretch less when wet.
Log-in
Elongation and Elasticity: It's a Stretch

<table>
<thead>
<tr>
<th>Fiber</th>
<th>Original Length (A) (in. or cm)</th>
<th>Extended Length (B) (in. or cm)</th>
<th>Final Length (C) (in. or cm)</th>
<th>Percent Elongation</th>
<th>Percent Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$\frac{B - A}{A} \times 100$</td>
<td>$\frac{B - C}{B - A} \times 100$</td>
</tr>
</tbody>
</table>

1. 

2. 

3. 

4. 

Percent Elongation = $\frac{\text{Extended Length} - \text{Original Length}}{\text{Original Length}} \times 100$

Percent Elastic Recovery = $\frac{\text{Extended Length} - \text{Final Length}}{\text{Extended Length} - \text{Original Length}} \times 100$
Flammability: Smoke Signals

Astronauts, firefighters, welders, and race-car drivers are exposed to intense heat as part of their jobs. They depend on flame-resistant protective clothing and environments for protection. Although other jobs are less risky, everyone can benefit from a better understanding of the ways that fabrics respond to fire and of the terminology that describes that response.

**Gather these materials:**
- Candle
- Matches
- Aluminum foil
- Fabric swatches, 2 in. (5.0 cm) square (cotton, wool, nylon, fiberglass)
- Tweezers
- Log-in chart (p. 151)
- Pencil

**Allow enough time:**
- 20 to 30 minutes

**Try it:**

1. Light candle.
2. Drop a few drops of melted wax on a piece of aluminum foil and anchor candle in the wax.
4. Move fabric gently into flame and place on aluminum foil to observe whether it burns, melts, or does neither. *Do not hold burning fabric with tweezers.*
5. Log in observations.
6. Repeat with other swatches.
Don't stop now:

- Repeat the test, but substitute three different fabrics made of the same fiber (suggestions: cotton gauze, cotton corduroy, and cotton denim or wool challis, wool knit, and wool felt).
- Share, explain, and discuss "Terminology: The Burning Behavior of Textiles" (p. 150).
- Invite a firefighter or safety specialist to discuss fire prevention or local fire safety standards and regulations.
- Research Nomex, an aramid fiber often used in protective suits for firefighters.

Let's talk—and think—about what happened:

- Describe how each fabric reacted to the flame.
- Based on their flammability, how would you recommend using each of these fabrics?
- Do you understand the difference between noncombustible and nonflammable? Flame-resistant and flame-retardant?
- What flammability terms do you find confusing?
- When all samples were made of the same fiber, did you still observe differences in burning behavior?

Tips for leaders:

- Observe these precautions when working with an open flame:
  - Provide close supervision.
  - Remove personal articles from the work area.
  - Do not wear fuzzy sweaters or loose clothing.
  - Have water or fire extinguisher at hand.
  - Remind students not to blow on burning fabric or wave it in the air.
- Aluminum pie pans or candleholders placed on aluminum foil may be used to support the candles.
- Fiberglass is a skin irritant. Caution students not to touch fiberglass except with the tweezers. Do not allow students to take fiberglass samples out of the work area.
- Students often ask about the burning test for fiber identification. Although exploring mystery fibers in this way can be fun, accurate fiber identification is not easy. Students may be able to establish a fiber’s general category (cellulosic) but not be able to differentiate among the cellulosic fibers (cotton, linen, ramie, jute). Burning test instructions are available in most textile textbooks.
- For information on Nomex, write to E. I. du Pont de Nemours & Co., Fibers—Nomex, P.O. Box 80,010, Wilmington, DE 19880-0010.
- For information on carbon fibers, write to Amoco Performance Products, 4500 McGinnis Ferry Road, Alpharetta, GA 30202-3914.
**TERMINOLOGY: THE BURNING BEHAVIOR OF TEXTILES**

**Noncombustible** Will neither ignite nor give off vapors that will ignite when subjected to external ignition sources. Glass, asbestos, and inorganic fibers such as carbon and ceramic are noncombustible. Some noncombustible textiles melt. Noncombustible textiles unaffected by fire are sometimes referred to as fireproof.

**Combustible** Will ignite and burn or give off vapors that will ignite and burn when subjected to external ignition sources. Most textiles are combustible.

**Nonflammable** Will not flame when burning.

**Flammable** Will flame when burning. Most textiles are flammable.

**Self-extinguishing** Will cease to flame when the ignition source is removed. Wool will flame if it is very dry but otherwise will smolder when the ignition source is removed.

**Flame-resistant** flaming is prevented, terminated, or inhibited. These fabrics are still combustible and flammable but are less likely to burn than other textiles. Flame resistance results from

- using *inherently flame-resistant fibers* such as modacrylic and aramids.
- incorporating *flame-retardant chemicals into the fiber* at the time of manufacture. This is done for rayon, acrylic, polyester and nylon.
- applying *fire-retardant chemicals on the yarns or fabrics* where they may be absorbed into the fiber or simply coat the surface. Cotton, wool, polyester, and nylon are sometimes finished in this way.

**Flame-retardant** More resistant to fire because of chemicals that have been applied. These finishes may be nondurable (temporary), semidurable, or durable.
## Log-in
Flammability: Smoke Signals

### Fabric Response to Flame

<table>
<thead>
<tr>
<th></th>
<th>Burns</th>
<th>Melts</th>
<th>No Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wool</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nylon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiberglass</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Other observations such as color of flame, odor, and residue:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wool</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nylon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiberglass</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Water seems to roll off umbrellas and raincoats, but it is absorbed by sweatshirts and towels. Why do these textile articles act differently? At least three reasons can be offered: (1) These fabrics are made from different fibers, which have unique responses to moisture. (2) They are constructed differently—some are fuzzy, some are smooth. (3) Some of these fabrics have been treated with a chemical to enhance their water-repellent properties. Let's try to create a finish that will make ordinary cotton fabric say, "Rain, rain, go away."

**Gather these materials:**
- 4 plain weave cotton fabric swatches (washed muslin), 2 in. (5 cm) square
- Laundry or indelible marker
- Water-repellent finishes (Scotchgard or Zepel)
- Spray starch
- Paraffin, melted
- Aluminum foil
- Food coloring
- Water
- Water container
- Tongs or tweezers
- Medicine dropper
- Clock or watch

**Allow enough time:**
- 1 hour

**Try it:**
1. Label four cotton swatches as 1, 2, 3, and 4. Leave sample 1 untreated. Spray sample 2 with water-repellent finish; spray sample 3 with starch till stiff; dip sample 4 in melted paraffin.
2. Place dried fabric samples on aluminum foil.
3. Mix a few drops of food coloring in a small amount of water.
4. Drop one drop of colored water on each sample and observe what happens. Repeat.
5. Wait 3 minutes and observe samples again.
6. Lift each sample with tongs or tweezers and note whether water passed through fabric onto foil.
Don't stop now:
- Check the fiber content label on your raincoat.
- List at least five articles that should repel water.

Let's talk—and think—about what happened:
- Did the colored water form a bead on the fabric surface or did it soak into the fabric?
- Were the colored spots the same size and shape on all fabrics?
- Did the water pass through any of the fabrics to the foil?
- Did the results change after 3 minutes?

Tips for leaders:
- Follow manufacturers' instructions for applying starch and water-repellent finishes.
- *Use caution with hot paraffin.* An adult should melt the paraffin and should closely supervise the immersion of the fabrics. Use tongs or tweezers.
- If you are working with children less than 10 years old, you may prefer to apply the finishes before the experiment.
Moisture Response 2: Vapors, Vapors

Your raincoat might keep the rain out, but is it comfortable to wear? When your raincoat prevents the rain from moving inside, it might also prevent the evaporation of your perspiration to the outside. This causes your skin to feel damp and clammy. Fabrics that can stop the flow of liquids while allowing the passage of water vapor are breathable. This experiment compares the water and water vapor response of three fabrics. Can any of them breathe?

Gather these materials:
3 tin cans or glass beakers
Water
Fabric swatches, 4 in. (10 cm) square (cotton, nylon, Gore-tex)
3 rubber bands
Sink or dishpan
Hot plate or other heat source

Allow enough time:
1 hour

Try it:
1. Fill tin cans or beakers about half full of tap water.
2. Place fabric swatches over mouths of cans and secure with rubber bands.
3. Invert cans over sink or dishpan and observe whether liquid passes through fabric.
4. Place jars on hot plate or stove. Allow water in cans to boil.
5. Observe which fabrics allow steam to escape.
6. Turn off heat and allow jars and fabrics to cool.
Don't stop now:
- Put on one cotton glove and one plastic glove. Seal at the wrist with tape or rubber band. Clap hands for 1 minute. Remove gloves and observe how the skin looks and feels under each glove. Which glove material do you think breathes?
- Learn more about Gore-tex by contacting the manufacturer and collecting descriptions from mail order catalogs.

Let's talk—and think—about what happened:
- Which fabrics resisted penetration by the water? by the water vapor?
- Can you think of situations when you would want neither water nor water vapor to penetrate your clothing? (chemical exposures)
- In the glove comparison, was the skin dry or glistening with moisture?

Tips for leaders:
- Provide close supervision of boiling water.
- Gore-tex fabric is composed of a microporous polytetrafluoroethylene membrane that is laminated to a shell fabric and lined with another fabric. It contains 9 billion pores per square inch, each 20,000 times smaller than a drop of water but 700 times larger than a water vapor molecule. For more information on Gore-tex, write to W. L. Gore & Associates, P.O. Box 1130, Elkton, MD 21921. The company sometimes has available materials for the Gore-Tex Membrane Coffee Break Demonstration.
- Other breathable, water-repellent fabrics are Matrex and Imtex, available from Polyform, 506 Oakmead Parkway, Sunnyvale, CA 94086.
- Request free Comfort-Gard Barrier Fabric Mitt kits from Kimberly Clark Apparel Company, P.O. Box 658, Cleburne, TX 76033, telephone: 800-433-1824, fax: 817-645-5818.
Have you ever used an old rope to play tug-of-war with a puppy? You probably had a lot of fun dragging one another around the yard or over an imaginary line. But what happened when the rope broke? Did you or your puppy tumble to the ground? The same mechanical action occurs when a kite string snaps or when a hot air balloon cable is pulled apart. It is important to select fabrics that can withstand the amount of pulling force that you expect to encounter. Let's explore the general idea of yarn strength.

**Gather these materials:**
- 6 yarns, any type, 24-in. (61 cm) lengths (suggestions: nylon fishing line, cotton rug or crochet yarn, wool weaving yarn, acrylic knitting yarn, dental floss, rope)
- Weight container (suggestions: lightweight buckets or plastic containers for yogurt, margarine, cottage cheese, cream cheese, film, or hosiery)
- Stationary horizontal bar (suggestions: bar on a play set, banister, tree limb, or ask an adult to hold a broomstick)
- Weights (suggestions: canned goods, nuts, bolts, beans, wooden blocks, pennies)
- Log-in chart (p. 158)
- Pencil

**Allow enough time:**
- 45 minutes to 1 hour

**Try it:**
1. Examine yarns and predict which ones can withstand the most pulling force.
2. Connect one end of a length of yarn to a container. Either tie yarn to the bucket handle, pass it through holes near top of container, or secure yarn between lid and container.
3. Tie other end of yarn to a stationary horizontal bar.
4. Add weights to bucket until yarn breaks.
5. Log in number of weights that caused this breakage.
6. Repeat with other yarn samples.
Don’t stop now:
• Repeat the test with two of the same yarns twisted together. Compare the result to that of the single yarn.
• Repeat the test with two different yarns twisted together. Compare this result to the performance of the single and double yarns.

Let’s talk—and think—about what happened:
• Describe the two strongest yarns that you tested.
• Were larger yarns always stronger than smaller yarns?
• Were two yarns twisted together stronger than a single yarn?
• Can you devise another way to test the breaking strength of yarns?
• Brainstorm about how each yarn—weak or strong—might be used in aviation.

Tips for leaders:
• This experiment tested tensile or breaking strength, which is only one aspect of a yarn’s total strength. It is especially important in situations of large, longitudinal forces such as safety belts and parachute harnesses.
• Groups or pairs of yarns are usually stronger than a single yarn.
• When yarns of different fibers are twisted together, the overall strength may be increased if the characteristics of each yarn are compatible. In some cases, however, the stronger yarn will cut or abrade the weaker one, so little strength advantage is gained in mixing fibers.
Log-in
Strength 1: Take a Break Trial

<table>
<thead>
<tr>
<th>Yarn type</th>
<th>Number of weights to break each yarn</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td></td>
</tr>
</tbody>
</table>
Strength 2: Puncture and Tear

Picture a sunny day with a clear sky and a steady breeze. Put yourself in that picture flying your new kite. Suddenly, a strong wind carries your kite into a nearby tree. As you struggle to free your kite, you wonder if it will be punctured or torn. The answer might depend on the fabric used to make your kite. Let’s experiment with different types of nylon to see how weave structure and special finishes can affect bursting and tearing strength.

Gather these materials:
- Woven nylon, 6 in. (15 cm) square
- Sturdy container (cup, can, jar)
- Rubber bands
- Blunt pencils, chopsticks, or screwdrivers
- Woven nylon coated with urethane, 6 in. (15 cm) square
- Woven ripstop nylon, 6 in. (15 cm) square
- Log-in chart (p. 161)
- Pen or pencil
- Scissors

Allow enough time:
- 30 minutes

Try it:

Puncture (Bursting Strength)

1. Stretch nylon sample over cup, can, or jar and secure with a rubber band.

2. Hold pencil, chopstick, or screwdriver 5 to 6 in. (12.5 to 15 cm) above sample. Jab cloth several times until object breaks through.

3. Repeat steps 1 to 3 using coated nylon and ripstop nylon.

4. Compare amount of force necessary to break through each fabric, and complete Log-in chart. The most puncture-resistant fabric requires the most force and is ranked 1. The least puncture-resistant fabric requires the least force and is ranked 3.

Tear (Tearing Strength)

1. Hold nylon sample between thumb and forefinger of both hands.

2. Tear cloth by rotating one hand away from body and one hand toward body.

3. If cloth won’t tear, snip a 1/2-in. (1.5 cm) cut with scissors and try again, starting at cut edge.

4. Repeat steps 1 to 3 with coated nylon and ripstop nylon.

5. Evaluate the tear resistance of each fabric. The most tear-resistant fabric is the most difficult to tear and is ranked 1. The least tear-resistant fabric is easiest to tear and is ranked 3.
Don’t stop now:

- Try puncturing and tearing other fabrics that vary by weight, fiber content, and structure.

<table>
<thead>
<tr>
<th>Test Variable</th>
<th>Suggested Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabric weight</td>
<td>Woven cotton fabrics of different weights (denim, batiste, muslin)</td>
</tr>
<tr>
<td>Fiber content</td>
<td>Knitted fabrics of similar weight but different fiber content (cotton, polypropylene, nylon, polyester)</td>
</tr>
<tr>
<td>Fabric structure</td>
<td>Cotton fabrics of similar weight but different structures (knitted, woven, lace)</td>
</tr>
</tbody>
</table>

- List uses of materials in which puncture resistance is important (hot air balloons, water balloons, tents, tea bags, luggage, basketballs, trampolines, tires).
- List uses of materials in which tear resistance is important (parachutes, clothing, upholstery, umbrellas, backpacks, fabric-covered facilities such as tennis bubbles and sports domes).
- Research the history and uses of nylon.

Let’s talk—and think—about what happened:

- In the two experiments on page 159, the fabric samples were woven from nylon of approximately the same weight. One of the fabrics was coated with urethane; one had extra yarns woven in at vertical and horizontal intervals. Did you observe differences in the performance of these fabrics in regard to bursting and tearing strength? Describe.
- How could you strengthen fabric against puncture and rips?
- If you tested fabrics of different weights, what did you observe?
- Did you notice different behavior if you compared knits and wovens?
- If you tested fabrics of different fiber content, what did you learn?

Tips for leaders:

- Youth nine years old and younger may need assistance in securing fabric over the container.
- Remind participants to jab the pencil into the cloth with control. Be careful not to jab hands.
- If listed fabrics are not available, substitute whatever you can find in your local fabric or hobby shop. Check the curtain department for sheer nylons.
- Fabrics may also be ordered by mail (Unit 4: Sources for Activity Supplies).
- Note definitions of tearing strength, bursting strength, nylon ripstop, and nylon taffeta (Unit 4: Glossary).
- Write for educational leaflet #2139, Nylon Ripstop & Taffeta, from Coats & Clark, Dept. E21, P.O. Box 27067, Greenville, SC 29616. A fee is charged, but an educator discount is available.
Log-in
Strength 2: Puncture and Tear

<table>
<thead>
<tr>
<th>Bursting Strength</th>
<th>Tearing Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 2, 3</td>
<td>1, 2, 3</td>
</tr>
</tbody>
</table>

Woven nylon

Woven nylon with urethane

Ripstop nylon

1 = best resistance
2 = average resistance
3 = least resistance
Strength 3: The Sandpaper Stomp

Do your jeans have holes in the knees? How did this happen? Were you sliding on the gym floor or did you fall on the sidewalk? Although some kids cut holes in their jeans to be in style, most people do not want holes in their clothes. Have you ever tried to fly a kite that had a hole on one side? If so, it probably wasn't much fun. Whether you are selecting fabric for jeans or for kites, you want cloth that will stand up to abrasion. Test the abrasion resistance of several fabrics by rubbing them with sandpaper.

Gather these materials:
- 1 yd. (91.5 cm) each cotton plain weave fabric, cotton twill weave fabric, and cotton knit fabric
- Magnifying lens
- Sandpaper, 2 in. (5 cm) square
- Duct tape
- Music
- Timer
- Log-in chart (p. 164)
- Pencil

Allow enough time: 30 minutes

Try it:
1. Examine fabrics with magnifying lens. Predict which will be most resistant to rubbing with sandpaper.
2. Tape a 2-in.-square (5 cm) piece of sandpaper to each participant's right shoe.
5. Turn on music. Twist, rub, and stomp sandpapered shoes against fabric for 3 minutes.

**Don't stop now:**
- In the experiment above, participants used any motion they chose. This time, agree on one action that all will imitate. Time each person and compare the results.

**Let's talk—and think—about what happened:**
- All three fabrics were made of cotton, but they were constructed differently. Describe their appearance.
- How might the fabrics be used?
- What did you observe about making holes in fabric?
- Which fabric was the most resistant to abrasion?
- When everyone used the same motion for making holes, did it take the same amount of time? Why or why not?
- Do any of your clothes have holes?
- Think of other ways that fabrics abrade (elbows of clothing rub on tables, knees of jeans slide on floors, wind whips a flag back and forth against itself).

**Tips for leaders:**
- If children are wearing nice shoes, they may not want to use the duct tape. An alternative method is to rub the cloth by hand.
- You might substitute old textile articles such as sheets, curtains, and towels for yardage.
- Because the knit fabric moves and stretches, you should place a strip of duct tape across the middle both vertically and horizontally.
- With older youth, discuss the problems of standardized testing. It is not easy to analyze a product fairly. The same test done by the same person using the same fabric does not always yield the same results.
# Log-in

**Strength 3: The Sandpaper Stomp**

<table>
<thead>
<tr>
<th>Abrasion Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>Plain weave, Cotton</td>
</tr>
<tr>
<td>Twill weave, Cotton</td>
</tr>
<tr>
<td>Knit, Cotton</td>
</tr>
</tbody>
</table>

1 = best resistance  
2 = average resistance  
3 = least resistance
Unit 3
Apparel for Flight

Although aviator jackets are popular sportswear items, apparel for flight is designed for function rather than fashion. Fliers require garments that protect them and enhance their performance.
Work Clothes for the Aviator

Protection and performance are the primary concerns in the design of garments for flight, but sometimes these two functions are incompatible. Protective qualities such as impermeability and resistance are not often found in the same materials that enhance performance through comfort. The designer's job is to reconcile the needs of the wearer, the properties of available materials, and appropriate construction techniques.

Designing for Protection

Workers involved in aviation may need protection from dust, sound, chemicals, wind, water, cold, heat, and flying objects. Garment design features that best address these needs are seam integrity, layered systems, padding, and reinforced structures. Items such as hoods, aprons, and backpacks can fill special needs.

Designing for Performance

Both ground and air personnel share to some degree the performance requirements of thermal comfort, moisture comfort, dexterity and tactility, mobility, vision, and ability to communicate.

**Thermal comfort**

This occurs when the body temperature is at a safe level even though the environmental temperature may be higher or lower. In cold environments, the ability of a garment to provide insulation is important. Design features such as storm flaps, collars, cuffs, and waistband or belt alter the flow of air currents. Pockets, linings, and bulky seams add warmth. In hot environments, resistance to external heat is primary. Keeping cool is facilitated by light colors; loose fit; adjustable necklines, cuffs, and waistbands; zippered vents; artificial cooling systems; and easily opened closures.

**Moisture comfort**

This is affected by the moisture in the atmosphere and the perspiration of the body. Fabric properties such as water vapor permeability, water content, ability to wick, drying rate, and water repellency are most important, but garment closures and layers also play a role.

**Dexterity**

Dexterity is the ease with which a person can perform tasks with the hands.

**Tactility**

This is the ability to sense by touching. Both tactility and dexterity are affected by glove fit and thickness and the physical properties of the glove material.
Mobility

Mobility—range and ease of motion—usually refers to gross motor control. It is affected by fabric flexibility and elasticity; garment cut, fit, and weight; and the friction of a garment against the skin or other garments. A flexible, elastic fabric allows greater ease of movement because it decreases the energy required to move. Garment cut and fit interact. For example, rubber gloves molded to the relaxed, curved shape of the hand allow ease of movement even when closely fitted. Gloves cut as flat pieces force the hand to work more even if the fabric is elastic. Flat pieces can be made less restrictive through the use of darts, pleats, and tucks. Helmets and other heavy equipment inhibit movement, but even the added weight from the extra fabric incorporated for a baggy fit can reduce efficiency. Optimal clothing system design minimizes friction caused by multiple layers of fabric rubbing against one another.

Vision

This function may be affected by the use of eye protection, face protection, headgear, or a breathing apparatus. Both the field of vision and visual acuity—the ability to distinguish shapes and precise contrast boundaries—can be affected.

Communication

The ability to communicate can be particularly important in emergency situations. Respiratory equipment and face protection can significantly reduce volume and clarity of speech.
Astronauts must wear gloves for all their extravehicular activities. Yet space suit gloves can be uncomfortable and interfere with tasks. The gloves worn by Apollo astronauts on the moon caused much finger fatigue and abrasion during the lunar exploration. Designers for the space shuttle’s space suit emphasized flexibility in their pressurized gloves. But even with very flexible gloves, small parts and conventional tools can be difficult to manipulate. Try some simple activities while wearing different types of gloves to understand better the problems associated with working in space.

**Gather these materials:**

3 pairs of gloves made from different materials (include a range such as snug-fitting latex gloves, stiff rubber or plastic gloves, cotton gardening gloves, and a leather baseball mitt)

Miscellaneous tools and items for 2 activities (suggestions: stack 10 blocks, write a message, wire a plug, drop 10 pennies in a bottle)

Log-in chart (p. 171)

Pencil

Stopwatch or watch with second hand

**Allow enough time:**

30 to 45 minutes

---

**Try it:**


2. Select three types of gloves. Fill in log-in headings. Write task description along top of chart and glove identification in left-hand column.

3. With bare hands, perform and time each task. Log in time. Repeat each activity wearing gloves 1, 2, and 3.
Don’t stop now:
- Repeat the tasks using wool gloves and mittens.
- List situations in which people wear gloves for protection.
- Ask students to design other tasks for testing gloves.
- Ask your students to design tools that could help them overcome the limitations imposed by the gloves.

Let’s talk—and think—about what happened:
- Compare the difficulty of doing a particular task with and without gloves.
- How much did wearing gloves slow your performance?
- Which gloves are most comfortable to wear?
- Which gloves do you think are most protective?
- Did you observe a difference between using mittens and gloves?
- Do you think design is an important part of making garments work for us?
- Can you think of ways that designers can improve the flexibility of gloves?

Tips for leaders:
- Choose objects to manipulate according to the age and interests of the youth. For example, large wooden blocks are a sufficient challenge for 5- to 8-year-olds, whereas small, specialized Legos are more interesting for 9- to 12-year-olds.
Log-in
Space Suit Gloves

<table>
<thead>
<tr>
<th></th>
<th>Task 1 (seconds)</th>
<th>Task 2 (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare hands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glove 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glove 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glove 3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Sew a Stretchy Sack

Until recently, each astronaut was fitted individually for his or her space suit. This was necessary because space suits lacked flexibility. To meet performance requirements, the suit had to be shaped to the wearer’s exact measurements. In contrast, this sack is shaped to no figure yet it can adapt to anyone. Sew this stretchy sack and try the activity “Stretch It Out” (p. 174).

**Gather these materials:**
- Sewing machine or serger
- Thread
- Scissors
- Nylon/spandex knit fabric, 60 in. (1.5 m) square
- Measuring tape
- Straight pins
- Stretch band 1–2 in. (2.5–5 cm) wide and 44 in. (1.1 m) long
- Hook-and-loop fastener, 10 in. (25.5 cm) long, cut into two 5-in. (12.5 cm) pieces

**Allow enough time:**
- 45 minutes to 1 hour

---

**Try it:**

1. Fold sides of fabric together to form a tube.

2. Machine stitch or serge along length of tube, leaving a 22-in. (56 cm) opening beginning 8 in. (20.5 cm) from top.

3. Refold and sew along top and bottom.
4. Sew ends of stretch band together to make a circle.

5. Sew band around opening.

6. Attach two pairs of hook-and-loop fasteners to band.

7. Turn right side out.

Tips for leaders:
- Spandex fiber is sold as Lycra by Du Pont and as Glospan and Cleerspan by the Globe Manufacturing Company.
- Fabrics with spandex can be safely laundered or dry-cleaned. Use neutral detergents because spandex is damaged by alkalis. Tumble dry at low temperatures or air dry. Do not use chlorine bleach.
Stretch It Out

When astronauts are in space, they experience “apparent weightlessness.” The blood shifts from the lower part of the body to the upper part, causing the face to become fuller and the waistline and feet smaller. The vertebrae are not pulled down by gravity, so people “grow” an inch or so. The joints move to their neutral position, which causes the body to bend slightly at the waist, the knees to flex, and the toes to point downward. These body changes and the microgravity environment affect the way a person moves. Try moving around inside a stretchy sack to isolate your body movements and to capture the sensation of living in space.

Gather these materials:
1 sack or bag made from stretchy fabric and large enough to cover a person (see “Sew a Stretchy Sack,” p. 172)
Magazine or newspaper

Allow enough time:
15 to 30 minutes

Try it:
1. Volunteer steps into sack and pulls it over his or her head.
2. Secure hook-and-loop fastener to close sack.
3. Person inside sack performs these exercises:
   - Raise one arm over head.
   - Kick one leg.
   - Bend from the waist and touch the floor.
   - Bend knees.
   - Take three steps forward and three steps backward.
   - Jump.
   - Turn around.
   - Touch someone.
   - Try to read a newspaper or magazine.
Don’t stop now:
- Have the person in the sack move around, isolating one joint or one limb and concentrating on how that works. People on the outside can observe what part of the sack is stretching.
- The body sack is flexible, so you can bend it in any spot. Space suits are less flexible. Have another person trace around the person’s body as they lie on a piece of butcher or wrapping paper. On this outlined figure, mark all the points that need to bend so as to function comfortably.
- View the videotape 3-2-1 Contact: Weightlessness (see “Tips for leaders”).

Let’s talk—and think—about what happened:
- Have the volunteer describe the way she or he moved while enclosed in the sack.
- How long did it take to adapt movements and become comfortable in the sack?
- Do you think people move faster or slower in a microgravity environment?
- Could the volunteer read printed text through the cloth?
- Do you think an astronaut’s vision is impaired by the headgear of a space suit?
- How can activities like this be used to design clothing that is more comfortable and more functional?

Tips for leaders:
- Make a body sack (“Sew a Stretchy Sack,” p. 172) or purchase a BodySox from S&S Worldwide (Unit 4: Sources for Activity Supplies).
- Purchase the videotape 3-2-1 Contact: Weightlessness (Unit 4: Sources for Educational Materials, NASA CORE).
Pleats Galore

Do your trousers have pleats at the waistband? Does your sister wear skirts that have kick pleats? Those little fabric folds expand to make you more comfortable or to let you move faster. They obligingly collapse when not needed. Pleats are sometimes popular for fashion, but they are always popular for work and sports clothing. Let's see how they work.

**Gather these materials:**
- 2 or more different lengths of "pleated" hoses or tubes (suggestions: vacuum cleaner hoses, flexible exhaust hoses for clothes dryers, collapsible cloth tunnels for youngsters)
- Tape measure
- Items to roll through hoses (suggestions: toy cars, marbles, balls)
- Timer

**Allow enough time:**
- 30 minutes to 1 hour

**Try it:**
1. Pleat or collapse first hose and measure collapsed length.
2. Extend hose and measure expanded length. Calculate percent extension:
   \[
   \text{Percent Extension} = \frac{\text{Expanded Length} - \text{Collapsed Length}}{\text{Collapsed Length}} \times 100
   \]
3. Hold extended hose in a horizontal position, resting on the floor or a table.
4. Try to roll marble, ball, or toy car through "tunnel."
5. Calculate rate at which it traveled:
   \[
   \text{rate} = \frac{\text{distance (expanded length)}}{\text{time}}
   \]
Don't stop now:
- Form teams and have a race through the "tunnels."
- Repeat the experiment, having participants crawl through the cloth tunnels.
- Examine an array of garments that have pleats. Compare the size and construction of the pleats.
- Read clothing catalog descriptions for different pleat names (box, kick, accordion, inverted, knife).

Let's talk—and think—about what happened:
- What was the percent extension of the two hoses?
- Were you surprised that pleats could make that much difference?
- At what rate did you roll the objects through the hoses?
- Did the pleats interfere?
- Describe the size and construction of some of the pleats you examined in garments.

Tips for leaders:
- Cloth tunnels are available in toy, department, and discount stores. Most are intended for small children.
Flex Time

Maintaining proper pressure in a space suit is essential for astronaut survival. Pressurized space suits can, however, be inflexible, which makes it difficult to work in space. Designers try to make space suits more bendable to increase the astronaut’s work efficiency. By placing metal rings at various points outside the pressure bladder (the balloonlike layer inside a space suit), the suit becomes bendable at these “joints.” Let’s look at the problem of joint movement.

**Gather these materials:**
- Tape measure
- Felt-tip marker (water-based)

**Allow enough time:**
15 to 30 minutes

**Try it:**
1. Ask youth to work as partners. One will be the subject, the other the designer.
2. Subject bends one elbow; designer makes a dot with the marker at the most prominent spot of elbow.

3. Subject straightens arm, allowing it to hang straight at his or her side.
4. Designer places a second mark 2 in. (5 cm) above elbow and a third dot 2 in. (5 cm) below elbow.
5. Designer measures exact length between top and bottom dots. It should be about 4 in. (10 cm).
6. Subject bends elbow again and designer measures distance between upper and lower marks.
7. Calculate change in arm length with elbow movement:
   - Change in arm length = Bent elbow measurement - straight elbow measurement.
8. Discuss how the designer can accommodate need for extra fabric in elbow area.
Don’t stop now:

- Your ideas for providing extra fabric at the elbow area of a sleeve might work for a regular garment, but will they work for an inflated garment such as a space suit? Let’s experiment with inflated balloons.

1. Fully inflate one long balloon and tie the end.

2. Inflate a second balloon, but slide bracelets or rings over it before it is completely inflated. The balloon should look a bit like sausage links. This may take practice if rings are slippery.

3. Inflate a third balloon and wrap rubber bands around it in two spots.

4. Try to bend all three balloons.

5. Discuss your observations.

Let’s talk—and think—about what happened:

- In what ways did you suggest altering the sleeve to allow for elbow movement? (longer sleeves, pleats or darts at the elbow, stretchy fabric, hole at the elbow)

- What did you observe when you tried to bend the balloons with and without the rings? the rubber bands?

- Where on the space suit would such joints be needed?

Tips for leaders:

- Practice placing the rings on the balloons before involving the students.

- Long balloons work best but are sometimes hard to find.
Color Me Hot, Color Me Cool

You might think white is an astronaut’s favorite color because the outer layer of a space suit is always that color. But the white suit is not a fashion statement. White fabric is less susceptible to rapid temperature changes than dark fabric. That is important when the astronaut is performing extravehicular activities. The sun may be burning one side of the body at 132°C (277°F) while the shady side drops to -118°C (-180°F). The following activity demonstrates how this works.

Gather these materials:
- 2 coffee cans with plastic lids
- Black fabric and white fabric, 16 in. (40.5 cm) square or larger
- Ice pick or skewer
- 2 thermometers (dial or glass)
- Flood lamp and light fixture
- Stopwatch or watch with sweep second hand
- Graph paper
- Pencils

Allow enough time:
30 to 45 minutes

Try it:
1. Put plastic lids on coffee cans.
2. Spread black fabric over outside of one can and white fabric over the other.
3. Punch a hole through center of cloth and each lid.
4. Insert one thermometer into each can.
5. Direct light from flood lamp at sides of both cans. It should be same distance from each can.
6. Take an initial reading on each thermometer and record temperatures every 2 minutes for 20 minutes.
7. Plot temperature data on graph paper using a solid line for the black can and a dashed line for the white can. Put temperature data along the y-axis (vertical) and time along the x-axis (horizontal).
Don't stop now:
- Repeat the experiment with fabrics of different colors such as red and green. Record these results on your graph.
- Allow the experiment to continue, reading the thermometers after 2, 4, and 8 hours.

Let's talk—and think—about what happened:
- Compare the steepness of the lines for the black and white cans. What does the steeper line indicate?
- Why do you think the black can was hotter?
- Did the cloth itself contribute to the temperature change? What test could you design to compare only the effect of color?
- What colors are typically worn in warm climates?
- Did the red and green fabrics act as you expected?
- Compare the results from the 20-minute and hour-long experiments.

Tips for leaders:
- On a summer day, use the sun's rays instead of the floodlights, but allow more time.
- If you have black and white cans or want to paint some, you can eliminate the fabric and its effects.
Log-in
Color Me Hot, Color Me Cool

Temperature (°F)

Time (minutes)
Are Space Suits as Hot as They Look?

Just looking at a space suit makes some people sweat. Yet we know that humans need protective garments to work in space. Can a garment protect the wearer and be comfortable? What are the tradeoffs? One of NASA's solutions to this problem is the liquid cooling garment (LCG), a space suit that circulates cool water through thin plastic tubing held close to the skin. Let's try it.

**Gather these materials:**
- Thermometer
- String
- Chair
- 50 ft. (15 m) small-diameter hose or plastic tubing with faucet attachment
- Source of water
- High boots
- Heavy raincoat
- Watch or clock
- Graph paper
- Pencils

**Allow enough time:**
- 45 to 60 minutes

**Try it:**
1. Attach thermometer to string.
2. Tie string around a volunteer's neck so thermometer is suspended at midchest level.
3. Record temperature.
4. Wrap hose around volunteer's midriff at least 20 or 30 times.
5. Attach one end of hose to a source of cool water and place other end in a drain. Do not turn on water yet!
6. Ask volunteer to put on boots and raincoat and to button raincoat completely. Have volunteer sit quietly on a chair.

7. After 5 minutes, record temperature.

8. Turn on water and let it flow for 5 minutes. Record temperature.

9. Ask volunteer to jog in place for 3 minutes and record temperature.

10. Repeat step 8.

11. Make a chart to show how temperature rose and dropped with different conditions.

12. Ask volunteer to explain any differences in comfort experienced.

---

**Don’t stop now:**

- List occupations that require a person to wear protective equipment that might cause heat stress.

- Collect descriptions of cooling garments from catalogs for sports enthusiasts and occupations involving high temperatures.

**Let’s talk—and think—about what happened:**

- How did the volunteer describe the hot-and-cold experience?

- Did the LCG cool the volunteer as quickly as you expected?

- Do you think the LCG would have had the same effect if it had been placed on the subject’s legs?

---

**Tips for leaders:**

- Any heavy clothing can be used to create the hot environment.

- Cooling vests are sometimes worn by agricultural workers and firefighters. You might borrow one from a friend or an agriculture supply store.

- A faucet allows good control of water pressure. Make certain that the tubing fits the faucet. Purchase an adapter if necessary.
Smashing Snickers

A stroll on the moon might mean an encounter with jagged rocks and zooming micrometeoroids. That’s why space suits have 12 layers of fabric and are pumped with air—for protection. We may not be able to duplicate all the special fabrics and the suit construction found in a space suit, but we can get an idea of how fabrics can protect us from impact injury.

Gather these materials:
- 1 bag miniature Snickers or other candy bars
- 2 pillows
- Life preserver
- Re-sealable plastic bag
- Backpack
- 2 shoulder pads
- Heavy book

Allow enough time:
- 15 to 30 minutes

Try it:
1. Place a miniature candy bar in each of these protective devices:
   - between two pillows
   - between the front and back of a life preserver
   - inside a re-sealable plastic bag filled with air
   - inside a backpack
   - between two shoulder pads (you may need to tape these together)
3. Separate pillows and check candy bar. If it is smashed, eat it!
4. Repeat procedure with each protective device.
5. Discuss effectiveness of each item in protecting the candy bar.

Don’t stop now:
- Try the experiment with lighter or heavier books, with other protective devices, or with harder or softer candies.

Let’s talk—and think—about what happened:
- Which protective devices worked? Which did not?
- List other devices that we use here on earth to protect us from impact injury (football pads, air bags, helmets, goggles). How are those devices similar? different?

Tips for leaders:
- You might invite a speaker to share safety information related to impact injuries.
- Some candy bars are amazingly sturdy. To see a difference among the protective devices, you may want to use a hammer or mallet for smashing. Remind participants of safety issues.
Pickpockets

Pockets are an important feature of our clothes. They provide convenient access for the many small items that people carry, such as keys, pens, notes, and change. Pockets can also be an important functional feature specifically designed to hold important supplies and tools. This is the case with the pilot, the astronaut, and the carpenter.

Gather these materials:
Students should be wearing garments with many pockets
At least 6 items for each participant (pencil, handkerchief, erasers, sunglasses, folded paper, paper clips, keys)
Stopwatch or watch with second hand

Allow enough time:
20 to 30 minutes

Try it:
1. Ask participants to hide items in their pockets.
2. Call for items one by one.
3. Note how long it takes to find each object.

Don't stop now:
• Repeat the exercise, but this time participants have to hold each item in their hand until all items are retrieved.
• Sew a carpenter's apron to use for art, sewing, or even carpentry.

Let's talk—and think—about what happened:
• How long did it take you to find the first item? the last item?
• Were you faster or slower at locating the last item?
• Why do people put certain things in specific pockets?
• When you repeated the activity, were you able to hold all the items in your hands?
• If you had no pockets, how could you secure these items to your garments?

Tips for leaders:
• A construction guide, Carpenter Apron, included in the 4-H Clothing Project Supplementary Materials, is available from Cornell Media Services Resource Center (Unit 4: Sources for Educational Materials).
• The Work Apron (#3301) and Locker Caddy (#3189) construction guides are available from Coats & Clark, Dept. E21, P.O. Box 27067, Greenville, SC 29616. Order Stitch in Time 46:1–5, student leaflet (P.E. 2106A).
Make a Loop Fabric Vest
Construction Guide*

Gather these materials:
Loop fabric, ½ yd. (45.5 cm) of 60-in. (1.5 m) width material
Marker
Scissors
4 pieces ribbon or bias tape, 10 in. (25.5 cm) long
Sewing machine or needle
Matching thread
Pins or tape
Measuring tape or yardstick

Allow enough time:
1 hour

*Use the loop fabric vest for the following activity, “Velcro Dodgeball.”

Try it:
1. Fold fabric in half lengthwise and crosswise to locate center. Around center point, draw a circle about 6 to 8 in. (15 to 20.5 cm) in diameter for neck opening. Cut along drawn line. Enlarge if needed.

2. Leave vest as a rectangle or shape it. To shape it, leave fabric folded, place a mark on shoulder line 3 in. (7.5 cm) from neck opening. Place another mark on the side, 10 in. (25.5 cm) below shoulder line. Connect the two marks with a curved line. Cut along that line.

![Diagram of the vest construction](image-url)
At home, you may find it hard to keep your room neat. In space, astronauts have the same problem. But a messy desk in microgravity is much more serious than it is here on earth. In NASA space shuttles and space stations a neat working environment is essential. That's where hook-and-loop fasteners can help. Each astronaut is given a personal supply of 30 square inches (76 square cm) of precut adhesive-backed Velcro fastener to use as she or he needs on mission-unique tasks. To test the effectiveness of these fasteners, let's play Velcro dodgeball.

**Gather these materials:**
- Loop fabric vests (see “Make a Loop Fabric Vest,” p. 187)
- Ping-Pong balls
- Velcro (2 colors) hook fastener
- Score pad
- Pencil

**Allow enough time:**
Game time varies depending on the number of participants and their enthusiasm. It can be an evening's entertainment or just a quick break from other activities. Allow additional time for activities in “Don’t stop now.”

**Try it:**
1. Make hook balls by wrapping Ping-Pong balls with strips of adhesive-backed hook-and-loop fastener.
2. Divide activity space into two sections.
3. Select one person to record scores and two or three people to serve as dodgers. The dodgers put on vests and stand in one section of activity space.
4. Divide remaining participants into two teams, A and B. Members of teams A and B occupy other section of space.
5. Assign one color of balls to team A, the other color to team B.

6. At starting signal, teams B and A throw their balls at dodgers. Dodgers and throwers may move around within their designated area but cannot move outside of that area.

7. When a dodger is hit, he or she must yell out color of ball that touched vest. Ball must touch vest (not the person) to earn a score.

8. Scorekeeper tallies points in this way: 1 point—nonstick hits, 2 points—stick hits (ball sticks to vest).

9. Dodgers return balls to throwers; game continues until one team scores 25 points or available time is over.

---

**Don't stop now:**
Try these other hook-and-loop activities:

- **Magic Mitts** (paddles and ball game). Play pitch and catch with this popular game set. Compare the surface of a tennis ball to the surface of the Magic Mitts ball.

- **Cockleburs.** A cartoon in the *Wall Street Journal* showed two children pulling burrs from their clothes. One kid called them “Velcro seeds.” His confusion is understandable. Use a magnifying lens to compare cockleburs and hook-and-loop fasteners.

- **Effects of liquids.** Separate hook and loop pieces and place them in the following liquids: cooking oil, water, and vinegar. Leave for 10 minutes. Remove fasteners from liquids. Test to see if they still work.

- **The Velcro rap.** Use hook-and-loop fasteners to add percussion sounds to your favorite song.

**Let's talk—and think—about what happened:**

- How does a hook-and-loop fastener work?

- List several ways that astronauts use Velcro fasteners to improve their life in space.

- List several uses of hook-and-loop fasteners here on earth.

- What is the noise that hook-and-loop fasteners make an advantage or a disadvantage?

- What differences did you observe between the tennis ball and the Magic Mitts ball?

- List one similarity and one difference between cockleburs and hook-and-loop fasteners.

- What happened when you soaked the hook-and-loop fasteners in various liquids?

**Tips for leaders:**

- Remind participants to throw at the vest, not at the person.
Build a Space Suit

Outer space is a hostile place. It can be freezing cold or burning hot. It lacks atmospheric pressure and oxygen. Micrometeoroids pelt moon walkers. There are no grocery stores or pharmacies. List all the conditions of space and the needs of an astronaut. Then build a space suit. Be prepared to explain the function of all the items you use.

Gather these materials:
Raid your garage, workshop, and junk room for items that might be used to build a space suit (suggestions: coveralls, hats, boots, gloves, lengths of hose, plastic bags, boxes, helmets, knee pads, vests, rope, goggles, masks, tin cans, plastic containers, wire, embroidery hoops, balloons, aluminum foil, old kitchen appliances, camping equipment, and sports equipment).

Scissors or knives
Marking pens
Duct tape

Allow enough time:
30 minutes to 1 hour

Try it:
1. Discuss the hostile environment in space.
2. List the many needs of an astronaut and discuss how those needs can be met.
3. Divide participants into two teams. Each team should choose one "astronaut."
4. Place space suit parts in center of activity area. At starting signal, each team member selects one item and uses it to dress astronaut. Team members may select several items but only one at a time. They may use markers and scissors to reshape items and duct tape to attach items.
5. After 10 minutes (or when all items are exhausted), stop the action.
6. Ask each group to explain the function of the parts of the space suit that they created.
Don't stop now:

- View the videotapes Living in Space: The NASA Space Suit and 3-2-1 Contact: Living There (Unit 4: Sources for Educational Materials, NASA CORE).
- Research the history of the space suit.
- Arrange a telephone interview with an astronaut.

Let's talk—and think—about what happened:

- What two conditions in space do you think cause the most problems for astronauts?
- How many astronauts' needs were on your list?
- Did the suit you created address all of those needs?
- Do you think you would like to wear a space suit?
- If you could talk to an astronaut, what two questions would you ask?

Tips for leaders:

- Try to include some unexpected parts for the suit. (A flyswatter was the favorite item in one of the pretests for this activity.)
- Order printed materials about the space suit (Unit 4: Sources for Educational Materials).
- Borrow video footage of a particular astronaut or mission from Film Distribution Library, Johnson Space Center, Houston, TX 77058, telephone: 713 486 9606. Remember to return borrowed videotapes promptly.
- Arrange a telephone interview with an astronaut. Contact the CB/Astronaut Office, Johnson Space Center, Houston, TX 77059, telephone: 713-244-8857, fax: 713-244-8863. Explain your needs, provide date and time choices, state any preferences (you may ask for particular astronauts or specify more general qualifications such as a native of your state), and request biographical data. Be flexible—astronauts have busy schedules. It is not unusual for the assignment to be confirmed a week or less before the program.
Many people, agencies, institutions, companies, and organizations share your interest in flight. Each brings a different perspective—science, business, recreation, education—and each can contribute to your youth program. Explore this section to locate sources for activity supplies and educational materials, to collect ideas for speakers and field trips, to clarify definitions of technical terms, and to identify references.
Glossary

Abrasion resistance Ability of a fabric to resist wear caused by rubbing against other surfaces.

Absorbency Ability of one material to take up another material.

Air currents Flow of air, especially in a definite direction.

Airfoil Streamlined structure that is flat on the bottom and curved on the top. The leading edge is longer than the trailing edge.

Appliqué Surface decoration that is sewed, embroidered, glued, or otherwise attached to a fabric.

Aramid Manufactured organic fiber with extremely low flammability, high strength, and high chemical resistance. Nomex, Conex, Technora, and Kevlar are aramid brand names. They are used in protective clothing, ropes, cables, and tire cord.

Autorotation Self- or automatic rotation of an object owing to certain physical characteristics.

Batt Fibrous material used for insulation or padding. Fibers are usually cotton, wool, or polyester.

Bernoulli’s principle Scientific principle published by Daniel Bernoulli in 1738 that states that as the speed of a fluid or gas increases, the barometric pressure of the area it occupies decreases.

Bias Any diagonal that intersects the lengthwise and crosswise grains of a fabric. A true bias is at a 45-degree angle to any straight edge when grains are perpendicular.

Bias tape Fabric strips of varying widths that were cut on the bias. They have prefolded edges suitable for curved hems, casings, or decorative trim.

Breaking strength Test for tensile strength; the load required to break the material.

Bursting strength Ability to retain integrity under a distending force; resistance to puncture or rupture.

Carbon fiber Any fiber that is carbonized to 93 percent or greater. Most carbon fiber is used in composites.

Cellulosic fiber Textile fibers composed of cellulose, a carbohydrate made of long chains of glucose. Examples of natural cellulosic fibers are cotton, linen, ramie, hemp, jute, sisal, and abaca. Manufactured cellulosics include rayon, acetate, and lyocell.

Ceramic fabric Strong and lightweight fiber made from aluminum silicate.

Coated fabric Fabric to which a substance such as lacquer, plastic, resin, rubber, or varnish has been applied in firmly adhering layers to provide properties such as water impermeability.

Composite Article or substance of two or more constituents with reinforcing elements dispersed in a matrix.

Cotton fiber Unicellular plant fiber composed of almost pure cellulose.

Dacron Du Pont trademark name for polyester textile fiber. It has high strength and high resistance to stretching, chemical degradation, and abrasion.

Dexterity Ease with which a person can perform tasks with the hands.

Dirigible Controllable airship that is lighter than air, e.g., the rigid dirigible Zeppelin and the blimp.

Double-topstitched seam To make this seam, press plain seam open. Topstitch an equal distance from each side of seam line, catching seam allowances.

Drag Natural force in which air resists the movement of an object.

Drapery weight Narrow band of fabric with small weights embedded at intervals. Used to weight fabric items such as curtains.

Drogue Short, funnel-shaped device attached to the rear of a kite for improved stability.

Durability Ability of a textile to remain intact under conditions of mechanical stress.

Elasticity Ability of a stretched material to return immediately to its original length. It is expressed as the percentage of return from elongation toward the original measurement.
Elastomer Material that at room temperature can be stretched repeatedly to at least twice its original length, and upon immediate release will return to its approximate original length.

Elongation Amount of longitudinal extension that a fiber will accept without breaking. Expressed as the percentage of the original length.

Fabric Planar textile structure produced by interlacing yarns, fibers, and filaments.

Fiber Natural or manufactured material that has an extremely small diameter and a length at least 100 times this diameter.

Finish Chemical, mechanical, or thermal treatment of yarn or fabric to change its properties.

Flame resistant Describes a material that burns slowly or is self-extinguishing after removal of an external source of ignition. A fabric or yarn can be flame resistant because of the innate properties of the fiber, the twist level of the yarn, the fabric construction, or the presence of flame retardants.

Flame retardant Chemical compound that can be incorporated into a textile fiber during manufacture or applied to a fiber, fabric, or other textile item during processing to reduce flammability.

Flammability Ease of ignition and speed and length of burning time.

Fusible web Nonwoven textile with a bonding agent on both sides. Secures two layers of fabric together.

Gore Section of fabric that is narrow at the top and wide at the bottom.


Graphite fiber Fibers that are more than 99 percent carbonized.

Gravity Natural force that attracts objects to the earth.

Heavier-than-air flight Flight system in which the flying object weighs more than the surrounding air.

Hot cutter Tool that applies heat to cut and seal the cut edges of a material.

Kevlar Registered trade name of an aramide fiber made by Du Pont.

Knitting Method of constructing fabric by interlocking a series of loops of one or more yarns.

Latex Raw materials from which rubber is made.

Leading edge Front edge of a flying object.

Lift Upward force that overcomes the effect of gravity.

Lighter-than-air flight Flight system in which the flying object weighs less than the surrounding air.

Linen Cellulosic fiber obtained from the inner bark of the stem of the flax plant.

Loom Apparatus for weaving fabric.

Lycra Trademark name of spandex made by Du Pont and used in undergarments, active wear, and other garments requiring stretch.

Manufactured fiber Class name for fibers produced from substances that may be (1) polymers synthesized from chemical compounds, e.g., acrylic, nylon, polyester, polyurethane, and polyvinyl fibers; (2) modified or transformed natural polymers, e.g., alginic and cellulose-based fibers such as acetates and rayons; and (3) minerals, e.g., glasses.

Mylar Polyester film made from polyethylene terephthalate by Du Pont. It is strong, flexible, has excellent insulating qualities and good chemical resistance. Used for recording tapes, insulating film, sails, and fabrics.

Nomex Registered trademark name of Du Pont for a highly heat resistant aramide fiber.

Nonwoven fabric Web or mat of fibers held together by an applied bonding agent, mechanical interlocking, or by the fusing in the case of thermoplastic fibers.
Nylon fiber Manufactured petroleum-based fiber that exhibits excellent strength, flexibility, toughness, elasticity, abrasion, resistance, washability, ease of drying, and resistance to attack by insects and microorganisms.

Nylon, ripstop Tightly woven, plain weave nylon fabric that has a heavy thread woven into the fabric every 1/8 in. (3 mm) in both the warp and weft directions. This interwoven grid "stops rips," so that a puncture is contained within a small area.

Nylon, taffeta Tightly woven, plain weave fabric that has muted striations because the weft yarns are usually heavier than the warp yarns.

Olefin Manufactured fiber composed of at least 85 percent (by weight) ethylene, propylene, or other olefin units. It resists stains, sunlight, heat, and abrasion.

Permeability State or quality of being penetrable by air, fluids, or gases.

Plain weave Fabric construction that is made and repeats on two warp ends and two weft ends. In this simplest interlacing, the weft travels alternately over and under the warp yarn to give a checkerboard appearance.

Plastic A polymer that can be molded under heat and pressure.

Pleat Folds of fabric that provide fullness to a garment or product.

Polyester Manufactured fiber composed of at least 85 percent (by weight) ester of dihydric alcohol and terephthalic acid. It is highly resilient and resistant to sunlight and most chemicals.

Polyethylene An olefin fiber of high molecular weight.

Polymer A long-chain molecule composed of repeating monomer units.

Polypropylene An olefin fiber of extremely high strength, ultraviolet light, and heat resistance.

Puncture resistance See Bursting strength.

Rayon Manufactured fiber composed of regenerated cellulose. It is absorbent and resists ultraviolet light, alkali, and insect damage.

Resin Solid or semisolid natural organic substance or manufactured product that is amorphous and yellowish to brown, transparent or translucent, and soluble in alcohol or ether but not in water. It may be used as a fabric finish.

Rubber A manufactured fiber in which the fiberforming substance is comprised of natural or synthetic rubber. It is elastic, repels water, and resists electricity.

Seam Line formed by sewing pieces of material together.

Seam allowance Width of fabric between the seamlne and fabric edge.

Seam finish Technique used to secure the raw edge of a seam.

Seam sealant Product that when applied to the edge of a material will prevent that material from raveling.

Serge Machine used to sew pieces of material together.

Shuttle Device that carries weft yarns across the fabric web in the weaving process.

Silk Textile fiber made of protein and extracted from the cocoons of the silkworm. Silk is moderately strong, absorbent, and sensitive to acids, alkalis, and ultraviolet light. Spiders can also produce silk.

Spandex Elastomeric manufactured fiber composed of at least 85 percent of a segmented polyurethane.

Spectra Registered trademark of Allied-Signal for a fiber spun from a solution of ultra-high-molecular-weight polyethylene. It has unequalled strength yet is incredibly lightweight.

Tactility Ability to sense by touching.

Thrust Force that must be created to move an object.

Trailing edge The back edge of a flying object.

Twill Fundamental fabric construction characterized by diagonal lines as some yarns float over two or more yarns in staggered progression. The fabric is flexible, strong, and abrasion resistant.
Tyvek Registered trademark of DuPont for a spunbonded olefin fabric that is tear-resistant and inexpensive. Used for mailers, protective coveralls, and kites.

Updraft Warm air current that rises faster than an object falls.

Urethane Organic chemical compounds or resins that produce foams that are used to bond or laminate fabrics.

Velcro Trademark name of a hook-and-loop fastener.

Warp Yarns that run parallel to the selvage in woven fabrics.

Water repellent Resin, wax, or chemical applied to fabrics to change their response to water. Water-repellent fabrics shed water but are permeable to air and comfortable to wear.

Weave System or pattern of intersecting warp and weft yarns. Two basic weaves are plain and twill.

Weaving Process of interlacing a series of vertical, parallel threads (the warp) with a series of horizontal, parallel threads (the weft) to create a web.

Weft Yarn running from the selvage at right angles to the warp. Also called woof, filling, pick, and shot.

Welt seam To make this seam, press both allowances of plain seam to one side; trim inside seam allowance to 1/4 in. (6 mm). Topstitch, catching wide seam allowance.

Wicking Dispersal of moisture vertically or horizontally across a given area; the capillary action of fabrics.

Wool Fiber from the fleece of the sheep or lamb, the hair of the Angora or Cashmere goat, and specialty fibers from the hair of the camel, alpaca, llama, and vicuna.

Yarn Continuous strand of textile fiber, filament, or other material that can be made into a textile.

Zipper foot Sewing machine attachment that eases the task of sewing zippers.
Sources for Activity Supplies

Most of the materials you will need for the activities in this handbook are ordinary items that you might have around your home or school or that are available at fabric, grocery, hardware, office supply, hobby, sailing, or craft stores. If you prefer to order supplies by mail, some sources are listed below.

Aero-Motion
P.O. Box 4546
Santa Barbara, CA 93140
Telephone: 805-965-5123
Aero-props and whirlbirds

Bob Chaffin
P.O. Box 229
Commerce, TX 75429
Telephone: 903-886-7662
Fax: 903-886-8882
Ripstop nylon fabric

Central Coast Creations
P.O. Box 3643
San Luis Obispo, CA 93403
Telephone: 805-466-9379
Wing sock kits, pattern book, and hardware; soldering iron; ripstop nylon fabric

Clotilde, Inc.
Louisiana, MI 63353-3000
Telephone: 800-772-2891
Fax: 800-863-3191
Sewing notions

Crystal Tissue Company
Middletown, OH 45042
Telephone: 513-423-0731
Fax: 513-423-0516
Tissue for balloons and kites

Delta Education
Hands-on Science K-8
P.O. Box 3000
Nashua, NH 03061-3000
Telephone: 800-442-5444
Fax: 800-282-9560
Magnifying lenses, scissors, basic science equipment

Edmund Scientific Catalog Company
101 East Gloucester Pike
Barrington, NJ 08007
Telephone: 609-547-3488
General supplies

Estes Industries
1295 H St.
Penrose, CO 81240
Telephone: 719-372-6565
WATTS: 800-525-7561
Fax: 719-372-3419
Rocket kits

FABTEX
18 Donlon St.
Framingham, MA 01701
Telephone: 508-543-0637 or 909-596-3399
Ripstop nylon fabric

Fun & Fitness
701 East 38th St.
Sioux Falls, SD 57105
Telephone: 605-334-7209
Records and booklets, including Oh, Chute!

Green Pepper
941 Olive St.
Eugene, OR 97401
Telephone: 503-677-7684 or 541-689-3294
Nylon, Lycra, and Velcro loop fabrics, hardware

Hang-Em High Fabrics
1420 Yale Ave.
Richmond, VA 23224
Telephone: 804-233-6155
Kite fabrics and parts, eyelet tools, adhesives, and other kite-making supplies

Industrial Webbing Corp.
109 Croton Ave.
Ossining, NY 10562
Telephone: 914-762-7353
WATTS: 800-635-5252
Fax: 914-762-3884
Velcro hook-and-loop fasteners, velcrot loop fabric

Into the Wind
1408 Pearl St.
Boulder, CO 80302-5307
Telephone: 800-541-0314
Kite-making supplies, tools, kits, accessories

Kite Studio
5555 Hamilton Blvd.
Wescosville, PA 18106
Telephone/Fax: 610-395-3560
Nylon fabric

Levitt Industrial Textile Co.
15 William St.
Hicksville, NY 11801
Telephone: 516-933-7553
WATTS: 800-548-0997
Fax: 516-933-7554
Velcro hook and loop fasteners, Velcloth loop fabric

Marine Sewing
6801 Gulfport Blvd.
South Pasadena, FL 33707
Telephone: 800-713-8157
Fax: 813-347-1424
Ripstop nylon

Midwest Products Company
School Division
400 S. Indiana St.
P.O. Box 564
Hobart, IN 46342
Telephone: 219-942-1134
Fax: 219-947-2347
Airplane kits

Nancy's Notions
P.O. Box 683
333 Beichl
Beaver Dam, WI 53916
Telephone: 414-887-0391
Fax: 414-887-2133
How-to-sew books (including Let's Sew), videotapes, scissors, grommets, other notions
Nasco
901 Janesville Ave.
Fort Atkinson, WI 53538-0901
Telephone: 414-563-2446
Fax: 414-563-8296
or
4825 Stoddard Rd.
Modesto, CA 95356
Telephone: 209-545-1600
Fax: 209-545-1669
Scissors, tissue paper, straws, tape, glue, other general supplies

National 4-H Supply Service
7100 Connecticut Ave.
Chevy Chase, MD 20815-4999
Telephone: 301-961-2934
Fax: 301-961-2937
4-H frisbees, 4-H wind socks, model rocket kits, space posters, Let's Sew by Nancy Zieman, Blue Sky Below My Feet videotape

National Parachute Industries
P.O. Box 1000
47 East Main St.
Flemington, NJ 08822
Telephone: 908-782-1646
Fax: 908-782-5638
Ripstop nylon fabric

Paxton/Patterson and Graves-Humphreys
Central region:
5719 W. 65th St.
Chicago, IL 60638
Telephone: 312-323-8484
Fax: 708-594-1087

Northeast region:
1003A Greentree
Executive Campus
Marlton, NJ 08053
Telephone: 800-631-0158
Fax: 609-985-3457

Western region:
1001 W. Euless Blvd. #207
Euless, TX 76040
Telephone: 800-262-1909
Fax: 817-354-6962

Southeast region:
5330 Peters Creek Rd., Suite C
P.O. Box 13407
Roanoke, VA 24033
Telephone: 800-336-5998
Fax: 703-366-0797
Model airplanes, rockets

Pitsco
P.O. Box 1708
Pittsburgh, KS 66762
Telephone: 800-835-0686
Fax: 800-533-8104
Books, videotapes, posters, rockets, airplanes, gliders

S&S Worldwide
P.O. Box 513
Colchester, CT 06415-0513
Telephone: 800-243-9232
Fax: 203-537-2866
Frisbees, parachutes, gliders, airplanes, kites, Body Sox

TESTFABRICS
P.O. Box 420
200 Blackford Ave.
Middlesex, NJ 08846-0420
Telephone: 908-469-0446
Fax: 908-469-1147
Fabrics, yarns, staple fibers

Tiger Associates East
P.O. Box 1136
Auburn, NY 13021
Telephone: 315-252-0296
Posters of aircraft

Sources for Educational Materials

Aviation Agencies and Organizations

Academy of Model Aeronautics
1810 Samuel Morse Dr.
Reston, VA 22090
Telephone: 703-435-0750
Information on building and flying model aircraft

American Kitefliers Association
352 Hungerford Dr.
Rockville, MD 20852
Telephone/Fax: 800-252-2550
Publishes Kiting magazine

Aviation Distributors and Manufacturers Association
1900 Arch St.
Philadelphia, PA 19103
Telephone: 215-564-3484
Newsletter, scholarships, student airport tours brochure

Aviation Exploring Division
Boy Scouts of America (BSA)
1325 Walnut Hill Lane
P.O. Box 152079
Irving, TX 75015
Telephone: 972-580-2427
Fax: 972-580-2502
Information about national BSA aviation exploring program

Balloon Federation of America
P.O. Box 400
Indianola, IA 50125
Telephone: 515-961-8809
Information about ballooning and balloon festivals

Cessna Aircraft Company
Air Age Education
P.O. Box 7704
Wichita, KS 67277
Telephone: 316-941-6192
Aviation education materials
Civil Air Patrol
105 South Hansell St.
Building 714
Maxwell AFB, AL 36112-6332
Telephone: 334-953-5387
Fax: 334-953-4235
Aerospace education programs. Call 800-I-CAN-FLY for flight school information for youth groups.

Experimental Aircraft Association
EAA Aviation Center
P.O. Box 3086
Oshkosh, WI 54903-3086
Telephone: 414-426-4800
Information on sport aviation, aerobatics, antique and classic aircraft; sponsors “Project School Flight” and Young Eagles Program.

Exploring Director
Crossroads of America Council
615 North Alabama St.
Indianapolis, IN 46204
Telephone: 317-925-1900
Information on aviation activities

Helicopter Association International
1619 Duke St.
Alexandria, VA 22314-3406
Telephone: 703-683-4646
Publications about helicopters

National Air and Space Museum
Office of Education
6th St. and Independence Ave., SW
Washington, DC 20560
Telephone: 202-357-2700
Educational information on aviation and space

National Association of State Aviation Officials
Metro Plaza One
8401 Colesville Rd., Suite 505
Silver Spring, MD 20910
Telephone: 301-588-0587
Educational materials for all aviation sectors

The Ninety-Nines
International Women Pilots
Will Rogers World Airport
Oklahoma City, OK 73159
Telephone: 405-685-7969
Information on female aviators

U.S. Department of Transportation
Federal Aviation Administration
Aviation Education, APA 100
800 Independence Ave., SW
Washington, DC 20591
Telephone: 202-267-3788
Extensive information on aviation careers, curricula, teaching materials, safety, videos

Young Astronauts
P.O. Box 65432
1308 19th St., NW
Washington, DC 20036
Telephone: 202-682-1984
Information and activities related to space education

Cornell University Media Services Resource Center
7-8 Cornell Business & Technology Park
Ithaca, NY 14850
Telephone: 607-255-2091
Fax: 607-255-9946
E-mail: dist_center@ece.cornell.edu
Web site: http://www.cce.cornell.edu/publications/catalog.html

Videotapes
The Fabric/Flight Connection
Blue Skies Below My Feet: Adventures in Space Technology

Handbook
The Fabric/Flight Connection

4-H Clothing Supplementary Materials
329REN3665

National Aeronautics and Space Administration (NASA)

NASA CORE
Lorrain County JVS
15181 Route 58 South
Oberlin, OH 44074
Telephone: 216-774-1051, ext. 293 or 294
Fax: 216-774-2144
Videotapes, computer software, slides, filmsstrips

NASA Educational Affairs
Education Publications Branch
3000 E. St., SW
Mail Code FE
Washington, DC 20546-0001
Telephone: 202-554-4380
Subscription to the newsletter Educational Horizons

NASA Educational Affairs
Elementary and Secondary Programs Branch
Code FE
Washington, DC 20546
Telephone: 202-358-1110
List of workshops and materials for teachers
<table>
<thead>
<tr>
<th>State</th>
<th>NASA Field Centers</th>
<th>NASA Teacher Resource Centers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska</td>
<td>Education Office</td>
<td>Education Office</td>
</tr>
<tr>
<td>Arizona</td>
<td>NASA Ames Research Center</td>
<td>NASA Ames Research Center</td>
</tr>
<tr>
<td>California</td>
<td>Mail Stop 204-12</td>
<td>Mail Stop 204-12</td>
</tr>
<tr>
<td>Hawaii</td>
<td>Moffett Field, CA 94305-1000</td>
<td>Moffett Field, CA 94305-1000</td>
</tr>
<tr>
<td>Montana</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nevada</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oregon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utah</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washington</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wyoming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connecticut</td>
<td>NASA Goddard Space Flight Center</td>
<td>NASA Goddard Space Flight Center</td>
</tr>
<tr>
<td>Delaware</td>
<td>Mail Stop 103.3</td>
<td>Attn: Teacher Research Laboratory</td>
</tr>
<tr>
<td>District of Columbia</td>
<td>Greenbelt, MD 20771-0001</td>
<td>Mail Stop 103.3</td>
</tr>
<tr>
<td>Maine</td>
<td>Telephone: 301-286-8570</td>
<td>Greenbelt, MD 20771-1000</td>
</tr>
<tr>
<td>Maryland</td>
<td></td>
<td>Telephone: 301-286-8570</td>
</tr>
<tr>
<td>Massachusetts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Hampshire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Jersey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New York</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pennsylvania</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhode Island</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vermont</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colorado</td>
<td>NASA Johnson Space Center</td>
<td>NASA Johnson Space Center</td>
</tr>
<tr>
<td>Kansas</td>
<td>Education and Information Services Branch-AP2</td>
<td>Attn: Educators Resource Lab.</td>
</tr>
<tr>
<td>Nebraska</td>
<td>2101 NASA Rd.</td>
<td>Mail Stop AP2 2101</td>
</tr>
<tr>
<td>New Mexico</td>
<td>Houston, TX 77058-3696</td>
<td>NASA Rd. 1</td>
</tr>
<tr>
<td>North Dakota</td>
<td>Telephone: 713-483-8696</td>
<td>Houston, TX 77058-3696</td>
</tr>
<tr>
<td>Oklahoma</td>
<td></td>
<td>Telephone: 713-483-8696</td>
</tr>
<tr>
<td>South Dakota</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Texas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Florida</td>
<td>NASA Space Center</td>
<td>NASA Langley Research Center</td>
</tr>
<tr>
<td>Georgia</td>
<td>Education and Services Branch</td>
<td>Attn: Langley Research Center</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td>Kennedy Space Center: FL 32899-0001</td>
<td>Virginia Air and Space Center</td>
</tr>
<tr>
<td>Virgin Islands</td>
<td>Telephone: 407-867-4090 or 9383</td>
<td>600 Settlements Landing Rd.</td>
</tr>
<tr>
<td>Kentucky</td>
<td></td>
<td>Mail Stop 164</td>
</tr>
<tr>
<td>North Carolina</td>
<td></td>
<td>Hampton, VA 23669-003</td>
</tr>
<tr>
<td>South Carolina</td>
<td></td>
<td>Telephone: 804-727-0900, ext. 757</td>
</tr>
<tr>
<td>Virginia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Virginia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Illinois</td>
<td>NASA Lewis Research Center</td>
<td>NASA Lewis Research Center</td>
</tr>
<tr>
<td>Indiana</td>
<td>Mail Stop 7-4</td>
<td>Attn: Teacher Resource Center</td>
</tr>
<tr>
<td>Michigan</td>
<td>21000 Brookpark Rd.</td>
<td>Mail Stop 8-1</td>
</tr>
<tr>
<td>Minnesota</td>
<td>Cleveland, OH 44135-3191</td>
<td>21000 Brookpark Rd.</td>
</tr>
<tr>
<td>Ohio</td>
<td>Telephone: 216-433-2017</td>
<td>Cleveland, OH 44135-3191</td>
</tr>
<tr>
<td>Wisconsin</td>
<td></td>
<td>Telephone: 216-433-2017</td>
</tr>
<tr>
<td>Arkansas</td>
<td>Mail Stop CL01</td>
<td>U.S. Space and Rocket Center</td>
</tr>
<tr>
<td>Iowa</td>
<td>Huntsville, AL 35812-0001</td>
<td>Attn: Teacher Resource Center</td>
</tr>
<tr>
<td>Louisiana</td>
<td></td>
<td>PO. Box 070015</td>
</tr>
<tr>
<td>Missouri</td>
<td></td>
<td>Huntsville, AL 35807-7015</td>
</tr>
<tr>
<td>Tennessee</td>
<td></td>
<td>Telephone: 205-837-5812</td>
</tr>
<tr>
<td>Mississippi</td>
<td>NASA Stennis Space Center</td>
<td>NASA Stennis Space Center</td>
</tr>
<tr>
<td></td>
<td>Mail Stop MA00</td>
<td>Teacher Resource Center</td>
</tr>
<tr>
<td></td>
<td>Stennis Space Center: MS 39529-6000</td>
<td>Bldg. 1200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stennis Space Center: MS 39529-6000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Telephone: 601-688-3338</td>
</tr>
</tbody>
</table>
Science Education Agencies and Organizations

American Association for the Advancement of Science (AAAS)
1333 H St., NW
Washington, DC 20005
Telephone: 202-326-6666
Activity packets and information on science careers

American Chemical Society
Distribution Office
1155 16th St., NW
Washington, DC 20036
Telephone: 202-872-8725 or 800-ACS-5558 or 800-333-9511
(for magazine subscriptions)
Science magazines and activity sheets

Eisenhower National Clearinghouse for Mathematics, Science, and Education
Ohio State University
1929 Kenny Rd.
Columbus, OH 43210-1079
Telephone: 614-292-7784
Fax: 614-292-2066
Information on aviation

4-H Aerospace
211 Duncan Hall
Auburn University, AL 36849-5620
Telephone: 205-844-2233
Skytlight newsletter

Great Explorations in Math and Science (GEMS)
Lawrence Hall of Science
University of California at Berkeley
Berkeley, CA 94720
Telephone: 510-642-7771
Fax: 510-643-0309
Hands-on science programs for youth

Textile Agencies and Organizations

American Apparel Manufacturers Association
2500 Wilson Blvd., Suite 301
Arlington, VA 22201
Telephone: 703-524-1864
Publications and videotapes

American Fibre Manufacturers Association
1150 Seventeenth St., NW
Suite 310
Washington, DC 20036
Telephone: 202-296-6508
Publications and videotapes

American Home Sewing and Craft Association
1375 Broadway
New York, NY 10018
Telephone: 212-302-2150
Sewing programs

American Sewing Guild
National Headquarters
P.O. Box 8476
Medford, OR 97504-0476
Telephone: 541-772-4059
Sewing publications and programs

American Sheep Industry Association
200 Clayton St.
Denver, CO 80206
Telephone: 303-771-3500
Information on wool; sponsors “Make It Yourself With Wool” contest.

American Textile Manufacturers Institute (ATMI)
1101 Connecticut Ave., NW
Washington, DC 20036
Telephone: 202-862-0500
Publications, films, videotapes

Bernina of America
534 West Chestnut St.
Hinsdale, IL 60521
Telephone: 847-394-4590
Sewing publications

Coats & Clark
Dept. E21
P.O. Box 27067
Greenville, SC 29616
Telephone: 864-394-4590
Books, leaflets, kits; inquire about educator price list.

Cotton Incorporated
1370 Avenue of the Americas
New York, NY 10019
Telephone: 212-586-1070
Publications and videotapes

E. I. du Pont de Nemours & Co.
Textile Fibers Division
Product Information Center
Wilmington, DE 19898
Telephone: 800-441-7515
Informational pamphlets

McCall Pattern Co.
Education Dept. 9119
615 McCall Rd.
Manhattan, KS 66502-9990
Telephone: 913-776-4041
Pattern and fashion information

Pendleton Woolen Mills
P.O. Box 3030
Portland, OR 97208
Telephone: 503-226-4801
Information about wool

Simplicity Pattern Co.
Educational Division
901 Wayne St.
Niles, IL 60712-0099
Telephone: 800-253-1555
Information on patterns

Velcro USA
406 Brown Ave.
P.O. Box 518
Manchester, NY 03108
Telephone: 603-669-4892
Brochures and samples
Museums

Airpower Museum
Antique Airfield
Otumwa, IA 52536
Mailing address:
Route 2, Box 172
Otumwa, IA 52501
Telephone: 515-938-2773

Allied Air Force Museum
Queen City Airport
1730 Vultee St.
Allentown, PA 18103
Telephone: 610-791-5122
Fax: 610-791-5453

American Association of Youths Museums
The Children's Museum of Houston
1500 BIN
Houston, TX 77004-7112
Telephone: 713-522-1138
Fax: 713-522-5747

Amherst Museum
3755 Tonawanda Creek Rd.
East Amherst, NY 14228
Telephone: 716-689-1440
Fax: 716-689-1409

Combat Air Museum
Forbes Field
Hangar 602
Topeka, KS 66619
Mailing address:
P.O. Box 19142
Topeka, KS 66619
Telephone: 913-862-3303
Fax: 913-862-3304

Confederate Air Force Museum
One Heritage Way
Valley International Airport
Harlingen, TX 78550
Telephone: 210-541-8585

Cradle of Aviation
Old Bethpage Village Restoration
Round Swamp Rd.
Old Bethpage, NY 11804
Telephone: 516-572-8401
Fax: 516-572-8413

Donald Douglas Museum and Library
P.O. Box 918
Santa Monica, CA 90406
Telephone: 310-392-8822

E.A.A. Air Adventure Museum
3000 Poberezny Rd.
Oshkosh, WI 54903-3065
Telephone: 414-426-4800
Fax: 414-426-4873

Empire State Aerosciences Museum
130 Saratoga Rd.
Scotia, NY 12302
Telephone: 518-377-2191
Fax: 518-377-1959

Fashion Institute of Technology
7th Ave. at 27th St.
New York, NY 10001-5992
Telephone: 212-760-7970

Frontiers of Flight Museum
Love Field Terminal
LB-38
Dallas, TX 75235
Telephone: 214-350-3600
Fax: 214-351-0101

Glenn H. Curtiss Museum
8419 Rte. 54
Hammondsport, NY 14840
Telephone: 607-569-2160

Helen Allen Textile Collection
University of Wisconsin
Madison, WI 53706
Telephone: 608-262-1162
Fax: 608-262-5335

Heritage in Flight Museum
Logan County Airport
Lincoln, IL 62656
Telephone: 217-732-3333

International Women's Air and Space Museum
26 North Main St.
Centerville, OH 45459
Telephone: 513-433-6766
Fax: 513-433-5979

Kalamazoo Aviation History Museum
3101 E. Milham Rd.
Kalamazoo, MI 49002
Telephone: 616-382-6555
Fax: 616-382-1813

Kansas Aviation Museum
3350 S. George Washington Blvd.
Wichita, KS 67210
Mailing address:
P.O. Box 485
Wichita, KS 67210-0485
Telephone: 316-683-9242

Kansas Cosmosphere and Space Center
1100 North Plum
Hutchinson, KS 67501-1499
Telephone: 316-662-2305
Fax: 316-662-3693

Mid-America Air Museum
200 W. 2nd St.
Liberal, KS 67901
Telephone: 316-624-5263

Mitchell Gallery of Flight
3173 S. 31st St.
Milwaukee, WI 53215
Mailing address:
5300 S. Howell Ave.
Milwaukee, WI 53215
Telephone: 414-383-4518

Museum of Flight
9404 F. Marginal Way South
Seattle, WA 98108
Telephone: 206-764-5700
Fax: 206-764-5707

Museum of Science and Industry
57th and Lake Shore Dr.
Chicago, IL 60637
Telephone: 312-684-1414
Fax: 312-684-7141
NASA LBJ Space Center
2101 NASA Rd. 1
Houston, TX 77058
Telephone: 713-483-4241

National Air and Space Museum
6th St. and Independence Ave. SW
Washington, DC 20560
Telephone: 202-357-2700
Fax: 202-786-2262

National Soaring Museum
Harris Hill Gliderport
R.D. 3
Elmira, NY 14903
Telephone: 607-734-3128
Fax: 607-732-6745

National Warplane Museum
Big Tree Lane, off Rte. 63
Geneseo, NY 14454
Telephone: 716-243-0690
Fax: 716-243-3032

Neil Armstrong Air and Space Museum
Box 1978
Wapakoneta, OH 45895
Telephone: 419-738-8811

New England Air Museum
Bradley International Airport
Windsor Locks, CT 06096
Telephone: 860-623-3305

Northeast Air Museum of the Connecticut Aeronautical Historical Association
Bradley International Airport
Windsor Locks, CT 06096
Telephone: 203-623-3305
Fax: 203-627-9083

Old Rhinebeck Aerodome
Rt. 1, Box 89
Rhinebeck, NY 12572
Telephone: 914-758-8610

Oregon Air and Space Museum
90377 Boeing Dr.
Eugene, OR 97402
Mailing address:
P.O. Box 8037
Coburg, OR 97401
Telephone: 503-461-1101
Fax: 503-484-0255

Southern Museum of Flight
4343 N. 73rd St.
Birmingham, AL 35206
Telephone: 205-833-8226
Fax: 205-836-2439

Strategic Air Command Museum
2510 SAC Place
Bellevue, NE 68005
Telephone: 402-292-2001
Fax: 402-292-9824

U.S. Air Force Museum
1100 Spaatz St.
Wright-Patterson AFB, OH 45433-7102
Telephone: 513-255-8042

U.S. Space and Rocket Center
One Tranquillity Base
Huntsville, AL 35807-7015
Telephone: 205-837-3400
Fax: 205-837-6137
References


The Fabric/Flight Connection
Evaluation

<table>
<thead>
<tr>
<th>Activity</th>
<th>Event</th>
<th>Participants</th>
<th>Completion</th>
<th>Comment/Suggestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetrahedron Kite</td>
<td>Camp</td>
<td>10 14-16 6 F, 4 M</td>
<td>2.5 hours</td>
<td>Students excited. Directions complicated.</td>
</tr>
</tbody>
</table>

Submitted by: Name ___________________________ Position ___________________________
Address __________________________________________________________________________
Agency/Institution __________________________________________________________________

Please return to Department of Textiles and Apparel, MVR 204, Cornell University, Ithaca, NY 14853-4401.
Telephone: 607-255-2009. E-mail: <cwc4@cornell.edu>.
The Fabric/Flight Connection handbook teaches principles of fiber science through the exciting story of aviation.

It also tells youth about nonapparel uses of textiles and encourages them to explore careers in science and technology.

The handbook suggests hands-on activities that encourage youth to

- discover how objects move through the air
- identify the essential characteristics of materials used in these objects
- understand the importance of design in aircraft and aviator clothing.

Projects vary in difficulty to accommodate audiences of many ages.

ISBN 1-57753-221-X