

KITE ENGINEERING: DESIGNING AND MAKING A KITE USING ADVANCED MATERIALS

WHAT YOU WILL LEARN

After completing this unit, you should understand:

- What a composite material is and why it is strong.
- The importance of strength and weight in a structure.
- How the strength of materials can be measured.
- That materials cannot be described as just 'strong' or 'weak'.

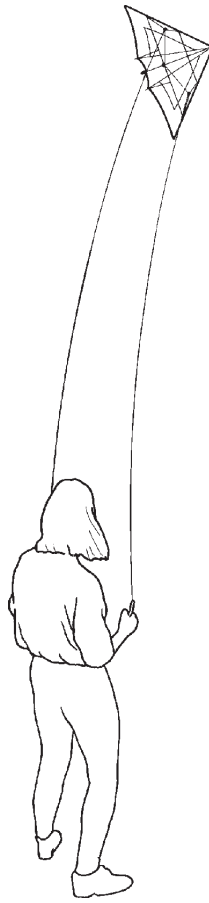
You should be able to:

- Recognise and name parts of a structure - e.g. ties and struts.
- Work to a design brief and write a specification.
- Carry out an investigation into one of the following.
 - i) Elastic materials.
 - ii) Strength of materials.
 - iii) Stiffness of materials.
- Recognise constraints when designing.
- Design and make a working kite.

STRUCTURES - KITE

During the last few years, kite flying has become one of the largest leisure growth industries. It has always been a popular hobby for a few but the availability of new materials has revolutionised kite design and construction and made them far more interesting to fly. There are now thousands of different kites on the market - many of them designed by engineers.

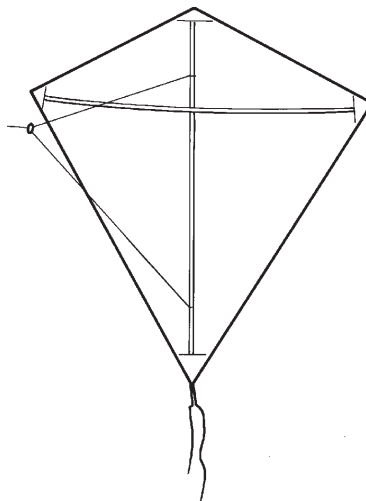
Kites are examples of structures. They are built from a number of parts and need to stand up to forces acting on them during flight. At the same time, they must be as light as possible. This unit introduces you to some basic principles of kite design. It also invites you to make a kite using advanced materials that have only just become available.



KITES AS STRUCTURES

A kite normally contains struts and ties. The struts are thin lightweight rods or tubes and ties are sometimes thin cord. The covering of a kite is a part of its structure and is subject to a stretching force when the kite is flying. The airstream has the effect of trying to stretch it.

A traditional diamond-shaped kite has two struts to give shape to the covering. The edges of such a kite might contain a stitched-in reinforcing thread (tie) to give additional tensile strength to the covering around its edge. In addition, there is a bridle tie which links to the tether or control line.



STRUCTURES - KITE

Many modern kites contain a number of struts and ties in a complex geometrical arrangement. (When we talk about the geometry of a kite, we mean the positioning of parts in relation to one another).

KITE MATERIALS

When a kite is flying, its various parts are subjected to dynamic loading. 'Dynamic' means that the loading varies - sometimes over a very wide range. The materials used in the kite therefore need to be able to withstand the highest loading they will get in normal use. A special case of dynamic loading is shock loading. When this happens, a force is applied very suddenly - e.g. it happens when a kite is caught by a sudden gust of wind. Structural failures often occur when this happens.

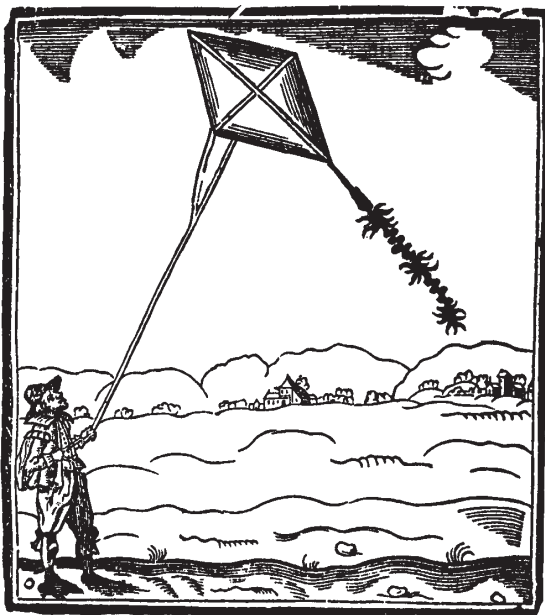
Before you can select materials for a kite (or any structure), you need to know how they behave under load. You can compare materials by means of simple experiments.

MATERIALS FOR KITE COVERINGS

The material for a kite covering must be light and possess high tensile strength. Ideally, it will also be waterproof. Materials currently used include:

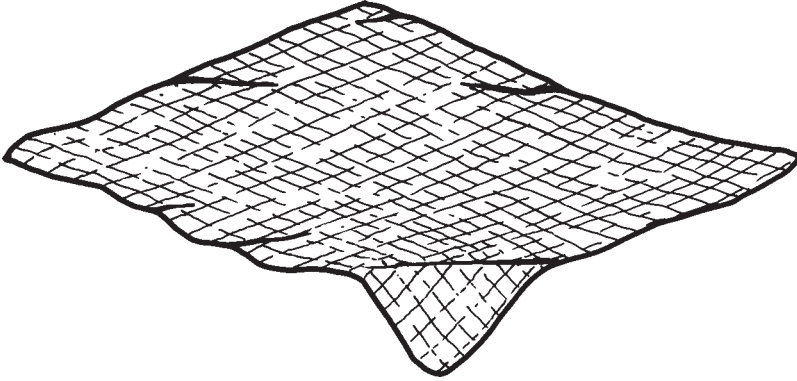
- Paper
- Plastic sheet
- Ripstop nylon.

Paper was the earliest lightweight material used in kite construction. It is light and strong but can be inflexible and tear easily.

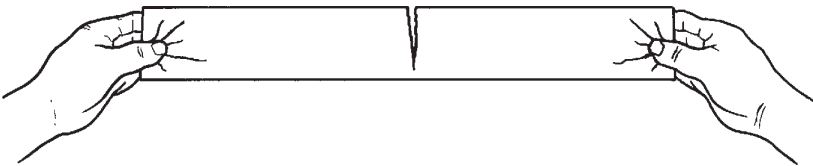


STRUCTURES - KITE

It is difficult if not impossible to break ordinary paper by trying to pull it apart. It fails easily though when you tear it. Many wrapping papers are now reinforced with thin plastic threads woven in at intervals



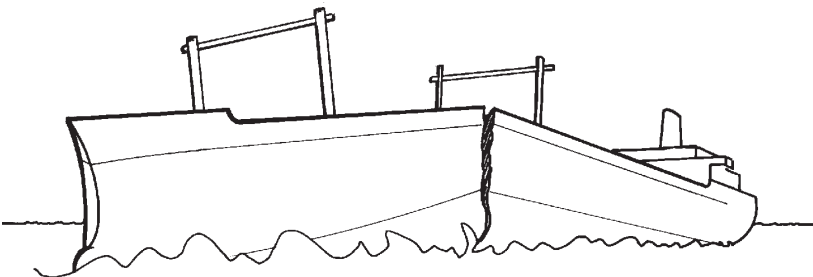
The main weakness of paper is its edge! A very slight cut at the edge, for example, can develop quickly into a tear. When a load is applied, it is concentrated on a tiny area at the tip of the cut and the tear **propagates** or moves through the paper.



◀ SCIENCE/MATHS OPPORTUNITY

Stress concentrations - simple calculations of stress and effects of large stresses on small area e.g. the tip of a crack.

The same problem can arise in other materials and structures and care must be taken to ensure that surfaces and edges are well finished. On a much larger scale, ships can break in half because of 'tears' or cracks which start at a weak point at the top of the hull.



PLASTIC SHEETING

Most plastic sheeting you come into contact with is low density polyethylene (LDPE or 'polythene' for short). It is used for carrier bags and other packaging.

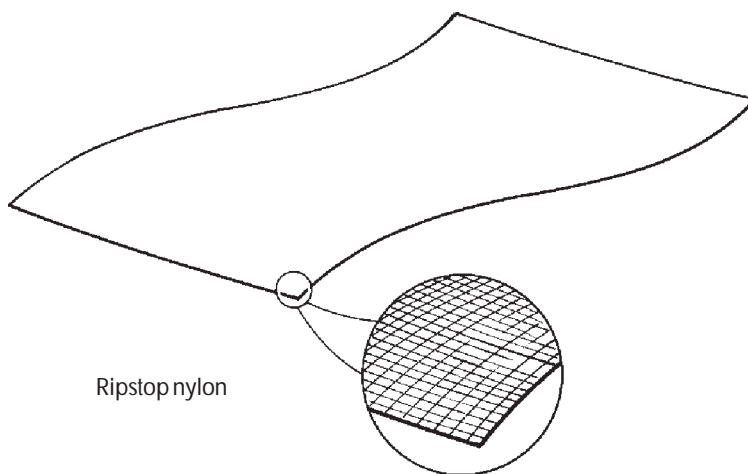


As carrier bags demonstrate, it has great tensile strength. An average carrier bag just a fraction of a millimetre in thickness can contain and support a load of 10 kg before failure - usually of the handles. Polythene exhibits elastic and plastic behaviour (though not quite like other materials). It must be used within its elastic limit. If it is loaded beyond this, it stretches and gets thin. Unlike paper, it has the advantage of not tearing easily.

Other sheet plastics are now available. These are very often co-polymers or a mixture of different basic plastics to give specific properties. The plastics used for 'clingfilm' have special surface properties and oven bags are resistant to high temperatures.

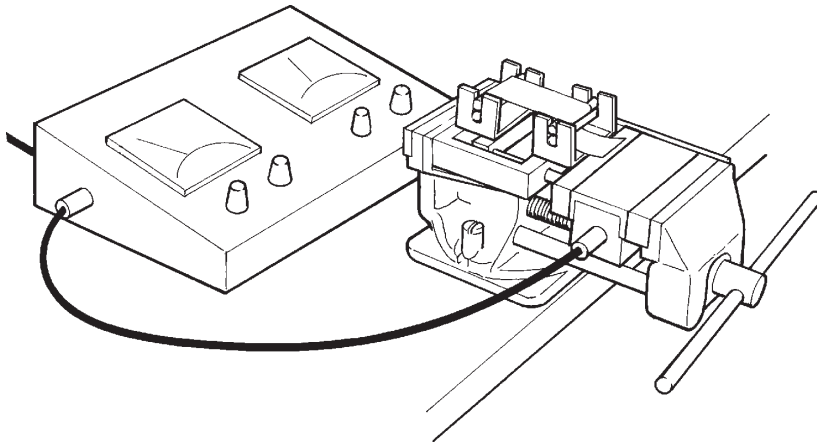
RIPSTOP NYLON

Ripstop nylon is a fabric woven from very fine nylon thread with additional strengthening threads in a square pattern. This pattern of threads prevents tears from moving through the material - hence the name 'rip stop'. It is normally coated with polyurethane. For its weight, ripstop nylon has exceptionally high tensile strength and resistance to tearing. It was originally developed for boat sails but is an ideal kite material.



INVESTIGATING COVERING MATERIALS

The standard test for tensile strength uses a machine called a tensometer. This stretches a material and shows its extension against the force applied.

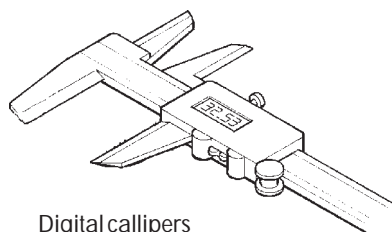
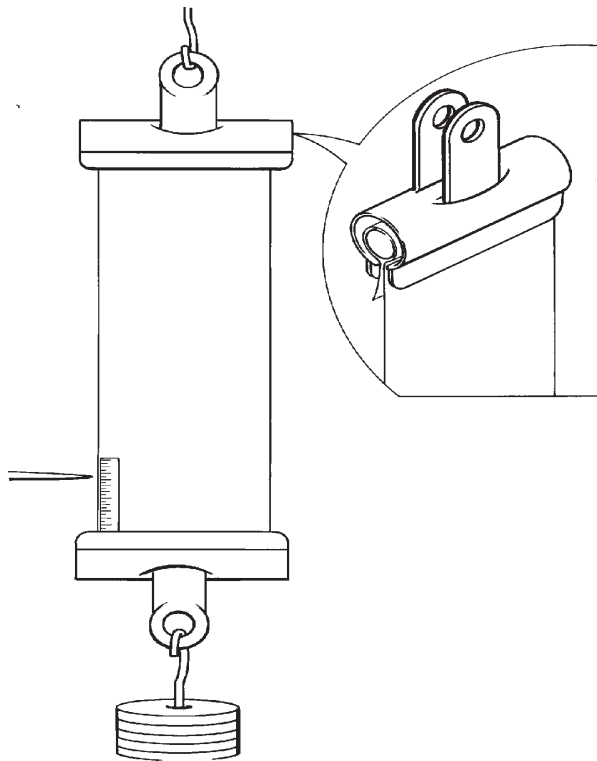


INVESTIGATING THE STRENGTH OF MATERIALS

Measuring the Extension

If a tensometer is not available, you can set up a very simple tensile test with strips of material (e.g. 20 mm wide \times 100 mm in length) held between two bulldog clips. A load in the form of weights is gradually applied and the extension is measured against a fixed point. The results can be compared on a graph.

For a fair test with different materials, the thickness must be the same. Thickness can be measured using digital callipers.



Digital callipers

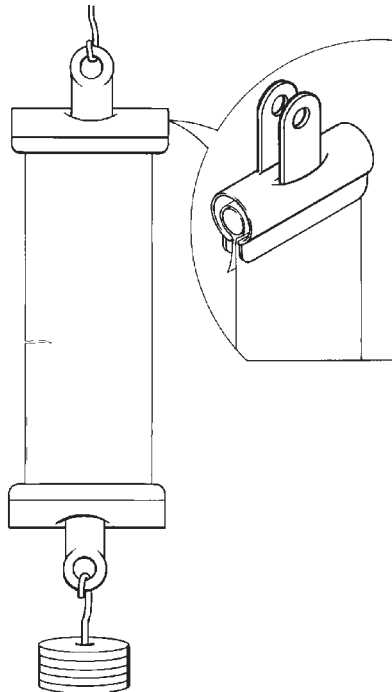
Other questions that could be answered include:

- 1) Using the same material, what difference does thickness make to the extension produced?
- 2) Does the width or length of the sample under test make a difference to the extension produced?

Investigating the Effect of Tears

Set up the tensile test shown here using a strip of paper (e.g. 50 mm wide × 100 mm in length) held between two bulldog clips. At the mid point make a small tear of 5 mm in length. Add loads until the paper rips. Repeat with tears of different lengths.

◀ SCIENCE OPPORTUNITY



Other factors that could be investigated include:

- 1) The length, width and thickness of the paper.
- 2) The position and size of the tear or cut.
- 3) The type of material.
- 4) The performance of the material when wet.

For a fair test, only one factor at a time must be changed (i.e. when testing different lengths, the width and thickness of the paper and the size of the tear must be the same).

MATHEMATICAL ANALYSIS

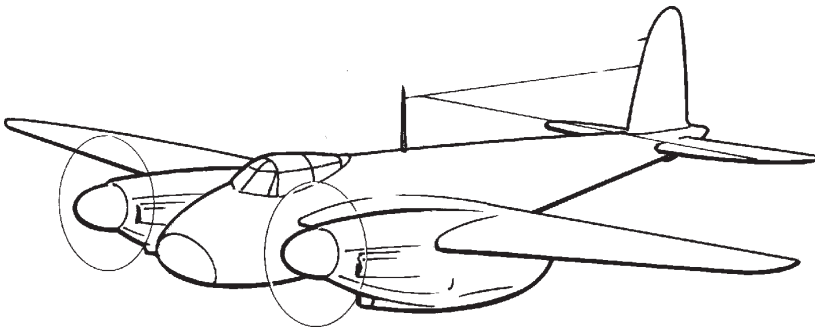
The results from the investigations above can be plotted onto graphs. Is there a link between the load required to rip the material and the size and position of the tear?

MATERIALS FOR STRUTS

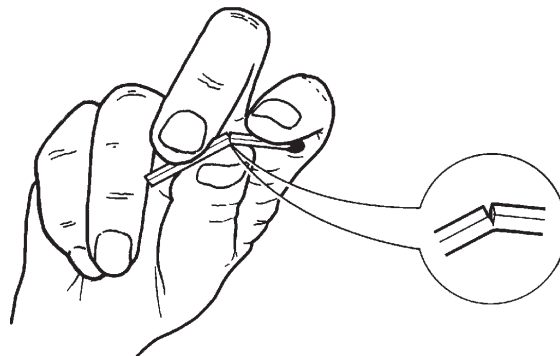
The materials used for struts must be light, stiff and possess high compressive strength. They should also have a **high strength to weight ratio**. Materials currently used include:

- Wood
- Metal (tubing)
- Reinforced plastic (rod and tubing).

Wood was the earliest lightweight material used in kite construction. You may find it surprising to learn that weight for weight, some woods are stronger than steel! An example is spruce which has been used extensively in aircraft construction because of its high strength to weight ratio.



Wood for kite construction is normally available in dowel (circular section) form. The main woods are pine, ramin and obeche. Dowels made from these woods are quite stiff but will flex quite considerably under load. When they break, it is normally a tensile failure that causes it. (If you bend a matchstick to break it, breakage will occur on the side of the matchstick in tension.)



METAL ROD AND TUBING

Metal tubing with a very thin wall is sometimes used in larger kites. The material is normally an aluminium alloy which is very strong and stiff in tube form. Shorter struts can be made from solid aluminium rod but this can only be used in short lengths because of its tendency to buckle and permanently deform. The suitability of different sections can be considered by comparing **elastic modulus**. This is a measure of stiffness.



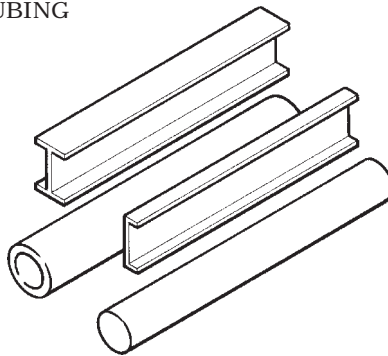
See Technology Study File 15.



See Technology Study Files 4 and 13.

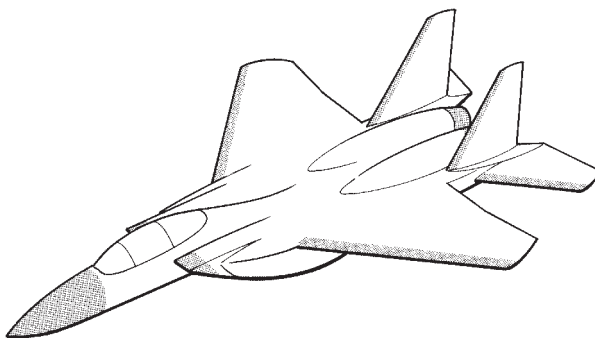
REINFORCED PLASTIC ROD AND TUBING

Although a range of plastics are available in tube, sections or solid rod form, many are too heavy for kite construction and not very stiff.

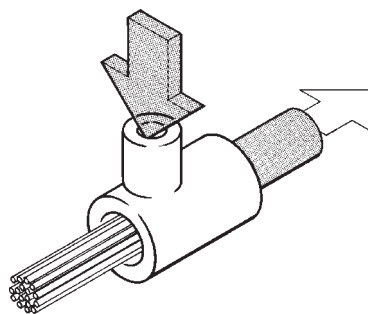


Fibre reinforced plastics combine high strength and low weight with great stiffness. This is because the basic plastic material provides high compressive strength and the reinforcing fibres embedded inside provide high tensile strength and resist movement.

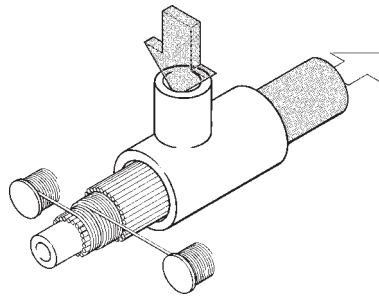
Cheaper reinforced plastic rod and tube is made from polyester resin with glass fibre reinforcement. (This is the material used in some car body shells.) A more expensive alternative uses carbon fibre reinforcement. Carbon fibres are immensely strong and are the basis of some 'hi tech' composite materials used in aerospace engineering.



Reinforced rods and tubes are made by a process called pultrusion (the opposite of extrusion). The reinforced material is pulled through a heated die where polyester resin is injected. A catalyst added to the resin causes it partly to cure as it passes through the die and to fully harden within hours.

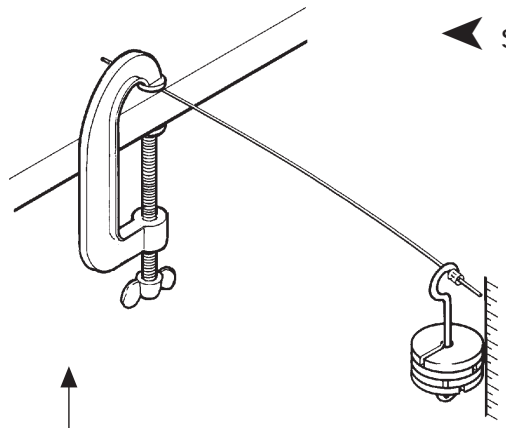


Carbon fibre tubes made by the pull-wound process have fibres wound around as well as along the tube. This results in tubes of low weight and exceptionally high stiffness.



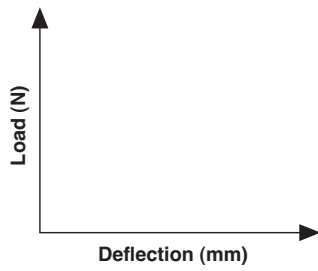
INVESTIGATING STRUT MATERIALS

You can compare the stiffness of possible strut materials and sections using a simple bending test. The rod or tube is clamped over the edge of a table with, for example, a 150 mm overhang. Weights are gradually added and the deflection is measured against a fixed point.



SCIENCE OPPORTUNITY

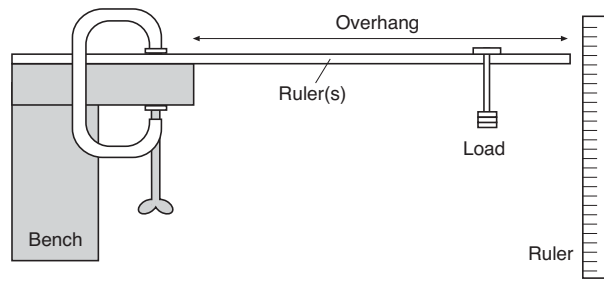
The results for different materials can be plotted and compared on a graph.



Warning: When you are using weights, take care to ensure that the weight container is close to the floor. Test pieces should be enclosed in a length of loose fitting flexible tube so that, if they break, the parts are safely contained.

FURTHER WORK ON STIFFNESS

In this experiment, the same set up is used but the number of variables tested is increased.



Questions

- 1) What effect does the load and its position have on deflection?
- 2) What effect does the length of the overhang have on deflection?
- 3) What happens to the amount of deflection when more than one ruler is used?
- 4) Does the length of the ruler make a difference to the deflection?
- 5) Do plastic rulers bend more than wooden rulers?

For a fair test, only one factor at a time must be changed (i.e. when testing different overhangs, the load and its position must be constant).

MATHEMATICAL ANALYSIS

The results obtained from the investigations can be plotted and compared on graphs. Is there a link between the factors investigated and the amount of deflection?

YOUR TASK

Design and make a working kite that can be taken apart and rolled or folded for storage. The kite is to be sold as a starter 'kit' for the growing leisure activity of kite flying. To keep costs low, the kite should have an area not exceeding 0.5m². The kite may use ripstop nylon and pultruded rod in its construction.

◀ DESIGN BRIEF

DESCRIBING YOUR TASK

First, you need to draw up a design specification for your kite. A specification is a more detailed description of what a product will be like, what it will do and who will use it.

◀ DESIGN SPECIFICATION

Here are some questions to help you produce your kite specification:

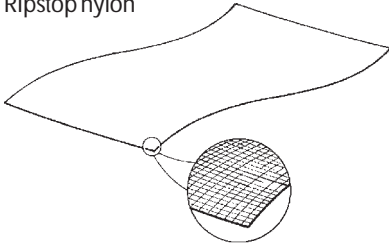
- *Who is the kite intended for?*
- *Where will the kite be used?*
- *Will the kite be folded or rolled?*
- *Will the kite require any special equipment for its assembly?*

WHAT YOU HAVE TO WORK WITH

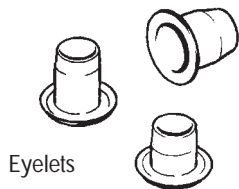
Before you get on with your design work, you need to know what materials and equipment are available. Your teacher will provide you with some of the materials listed below. Make a note of what there is.

◀ DESIGN CONSTRAINTS

Ripstop nylon

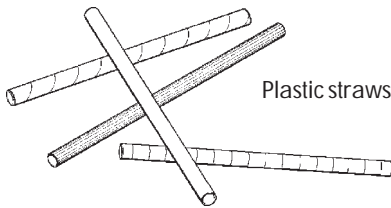
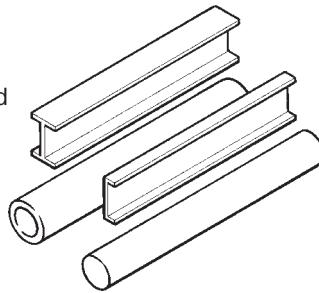


Paper
Plastic sheeting
Nylon cord

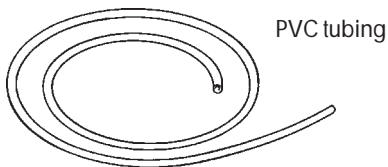


Eyelets

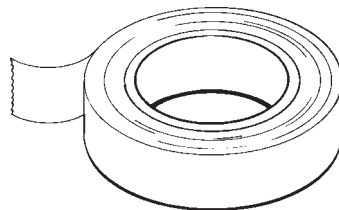
Pultruded rod
and tubing



Plastic straws



PVC tubing



Adhesive tape

DESIGN PROPOSALS

Once you know what materials and equipment are available, you need to think about ideas for the kite.

- Set your ideas down on paper.
- Play around with your ideas.
- Check your ideas against your specification.
- Decide which is the best design.
- Do a detailed drawing of the design.

You will need to end up with a working drawing from which you or someone else can work to mark out, make and assemble the parts. It is a good idea to draw the shape of the covering full size to act as a template for cutting out.

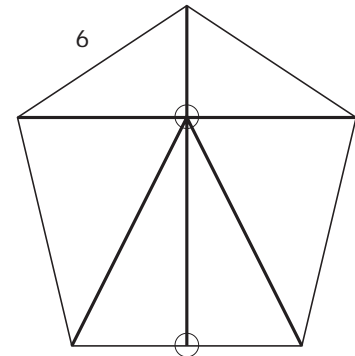
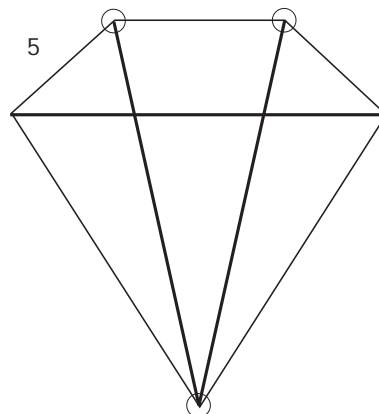
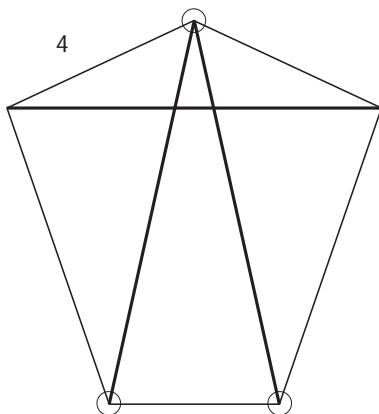
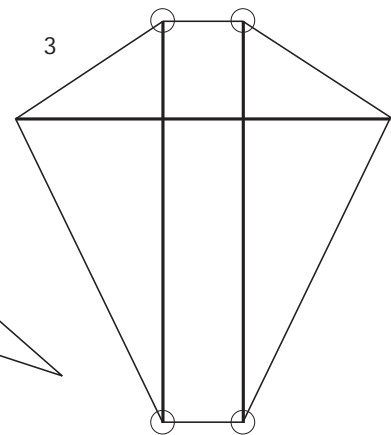
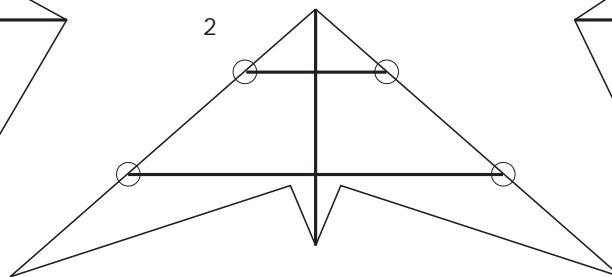
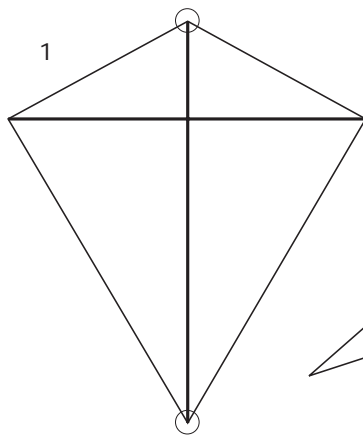
◀ NOTE

See Technology Study File 2.

Before you start, the following notes will give you some ideas about how the kite can be designed and made. They do not give you the answer though! You must make the important decisions and put all the 'ingredients' together so that you end up with a working product.

KITE GEOMETRY

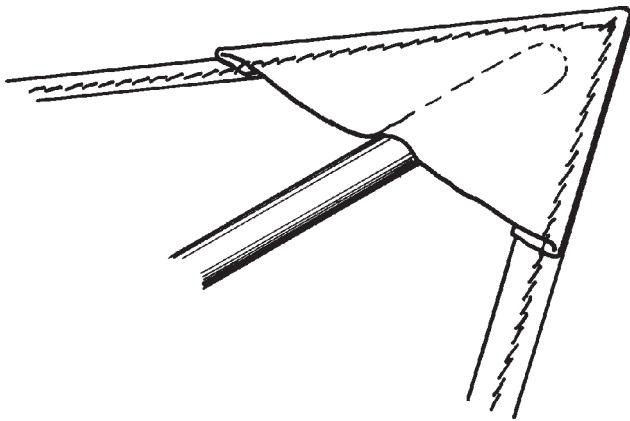
There are a wide number of well proven kite **geometries** or shapes. The outlines on this page provide you with some which can be measured and enlarged to a scale. For example, if you take shape 1, the widest measurement is 48 mm and the longest measurement 52 mm. If this is enlarged using a scale of 20:1, the kite will measure 960 mm by 1040 mm. You do not have to follow any of these shapes exactly, but remember the basic proportions have been proved to work. Other shapes are illustrated in standard books on kite design and construction. (After building your first kite and some further reading, you should be able to design some original shapes and even new types of kite). Please note that some kites such as shape 1 require a tail for stability. **The circles on the diagrams are anchor points for the kite line.**



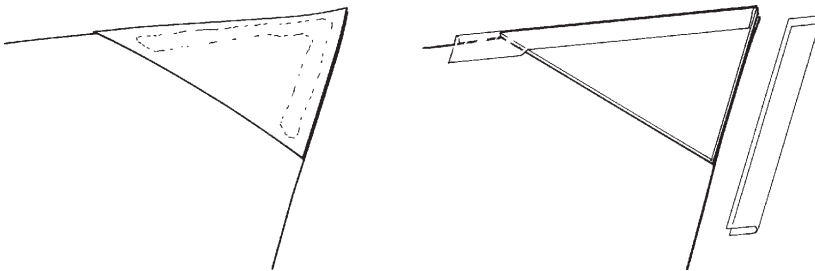
STRUCTURES - KITE

FITTING STRUTS TO THE COVERING

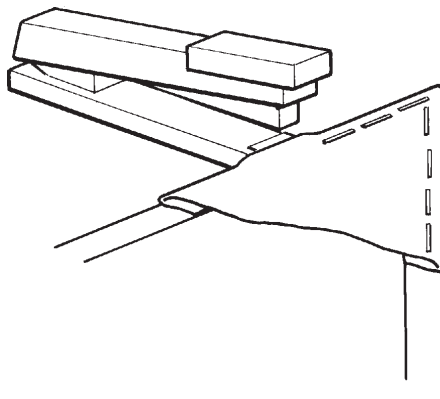
The parts used in kites have a variety of names such as 'spar', 'spreader', 'keel', 'leading edge' and 'spine'. For simplicity, we will refer to all of these as struts. In kite designs, the struts need only join the covering at points. The traditional way of joining is to locate the struts in corner pockets. How these are constructed depends on the material you use.



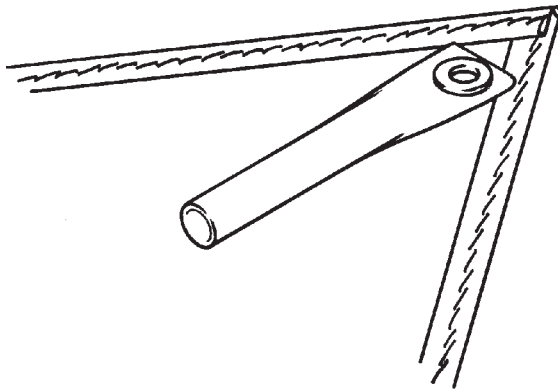
If you are using paper for a prototype, paper pockets can be glued on. For plastic sheet prototypes, you can use Sellotape.



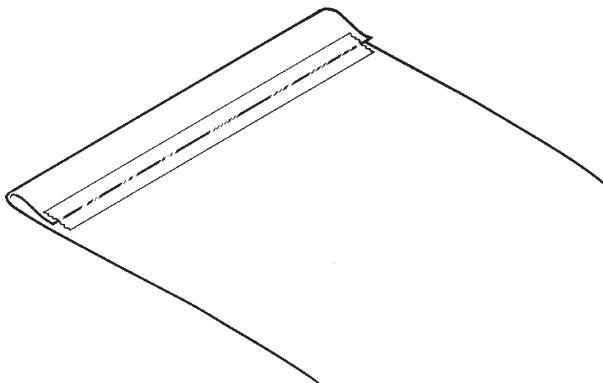
Ripstop nylon is normally stitched. Corner pockets can be formed by hand or by machine sewing. An alternative is to use staples.



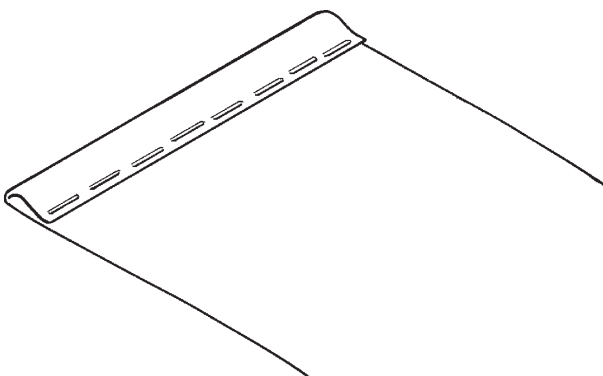
Pockets can also be formed by small lengths of plastic straw 'riveted' to the ripstop with eyelets. A combined eyeletter and closing tool is used to punch a hole in the straw and to close the eyelet. A leather punch tool or scalpel is used to make a hole in ripstop sheet. You may have to wind one or more layers of Sellotape onto the strut to make sure the tube is a tight fit.



Some shapes require struts along the edge of the covering and here they are normally put into a continuous pocket.



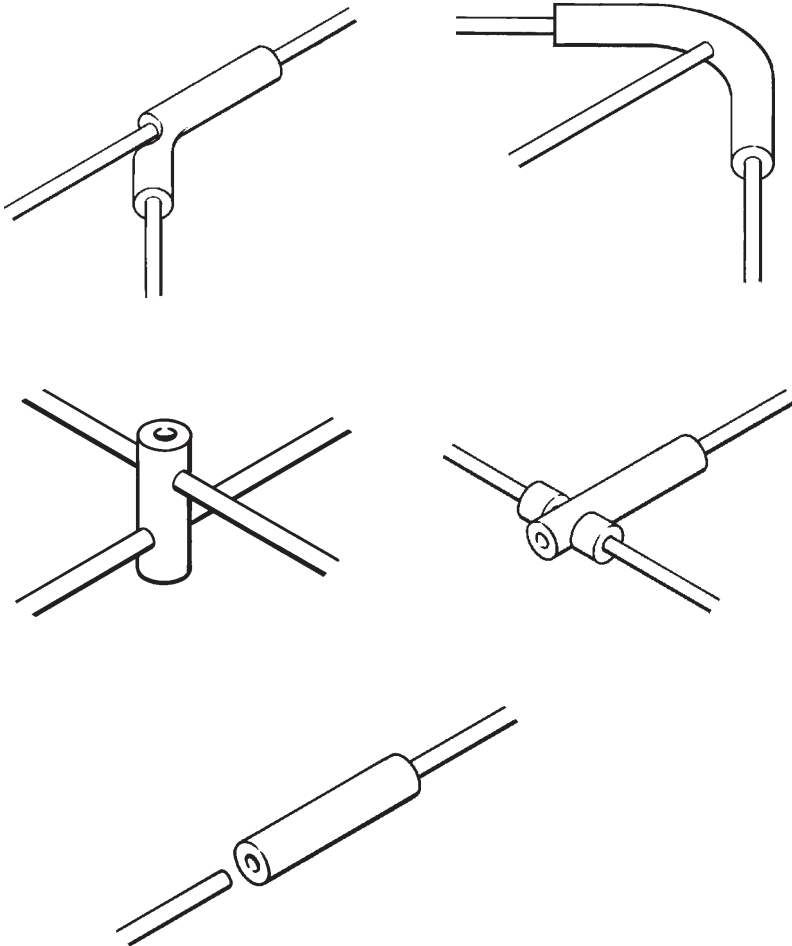
For paper and sheet plastic prototypes, the pocket can be formed using adhesive tape. For ripstop nylon, it must be done by sewing or stapling.



STRUCTURES - KITE

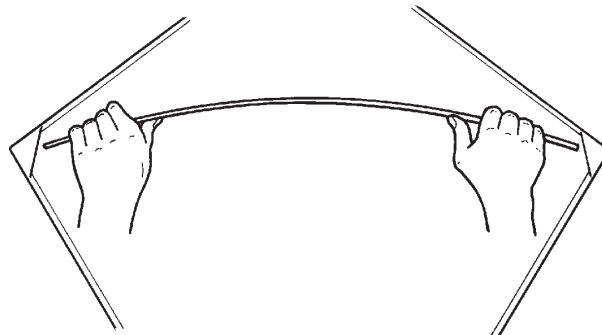
JOINING STRUTS

A number of special fittings are sold for joining kite struts together. An inexpensive alternative is to use tight fitting PVC tubing as shown. Holes are made with a leather hole punch or with a bradawl. The same tubing can be used on struts to prevent the bridle cords moving.



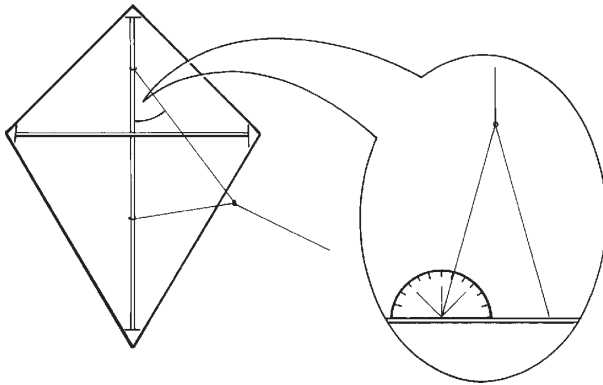
PUTTING IT ALL TOGETHER

When you are assembling a kite, you should be able to bend and 'spring' your kite struts into any pockets. Struts that pass through a continuous pocket should either be stitched or stapled in at the two ends. The fixings for the struts may need to be put on before the strut is passed through its pocket.



STRUCTURES - KITE

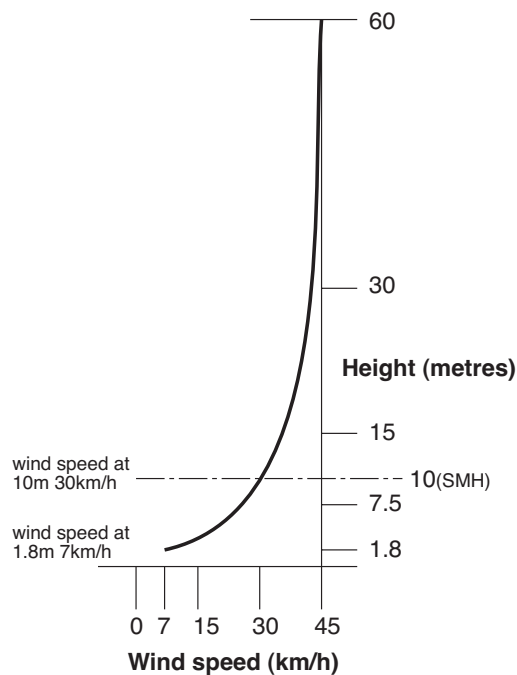
Once you have assembled the basic parts of the kite, you need to attach the bridle. All the kite shapes shown here use a 'two leg' bridle to which the line is attached. When the bridle is pulled into a 'V', the upper leg should be at an angle of about 70° to the surface of the kite. This angle can be measured with a protractor.



Some kites require tails for stability. These can be formed from scraps of materials from which the kite is made and might be one or two metres long. Pieces of material can be tied to the tail as decoration.

The graph below shows the variation of wind speed against height. Below the Standard Meteorological Height (SMH) of 10 m, wind conditions are affected by terrain.

Above SMH, the wind speed increases with altitude.



◀ SCIENCE OPPORTUNITY

STRUCTURES - KITE

EVALUATING YOUR KITE

There are a number of things to consider when evaluating the success of your kite:

- Does it meet the specification?
- Does it meet the requirements of a good structure?
- Does it fly without structural failure?

These questions can really only be answered by flying the kite. For the shapes shown, and using modern materials such as ripstop nylon, it should be possible to get the kite airborne in a moderate breeze. Windspeed tends to increase with altitude as the graph indicates and so once it has been pulled along to ascend the first few feet, the wind will start to take over. Flying conditions vary according to environment. High buildings and even large trees can have a significant effect on conditions.

Note: Never fly kites near overhead power or telephone lines or roads.