Aircraft design and structure teacher notes

Key Stage 3
Science:

- Scientific thinking
- Practical and enquiry skills
- Forces and motion

Key Stage 3
Design and Technology:

- Designing and making
- Critical evaluation
- Resistant materials

Overview of the activities

Four activities are described. They can be used in sequence or individually.

1. Helium balloons and lift
2. Airframes, strong structures and wing design
3. Propeller design
4. Parachute design

NOTE: a suitable risk assessment must be performed before carrying out any practical activity.

Activity 1: Helium balloon and lift

In this activity, young people investigate the amount of lift that is generated by one or more helium balloons.

Preparation and Materials

- Helium-filled balloons that float (typically available from card or gift shops). Tie three long cotton threads to each balloon – long enough so that balloons can be retrieved if they float to the ceiling. One per group of children.
  Use fine cotton thread so that the weight of the threads can be ignored.
- Small, lightweight plastic or paper disposable cups.
- Sand and plastic spoons (only a small amount will be needed per group).
  Can use any materials that can be added to the plastic cup in small amounts, e.g. sugar or salt if more readily available.
- Digital scales to weight the sand and cup.
- Sticky tape
- Activity sheet (attached following these notes)
- Flying machines presentation

Activity Notes

Show the presentation looking at the development of flying machines. Show how it has moved from lighter than air balloons to powered craft that generate lift due to their wings and movement of air.

Wan Hu's rocket chair is possibly the earliest attempt at powered flight. Contemporary reports suggest that this exploded, leaving no sign of Wan Hu or his chair. Perhaps he was the first man in orbit!

The Montgolfier brothers used hot air balloons. Modern ones are still seen today. Balloons will float where they are taken by the wind. Large airships, such as the Hindenburg, have engines and propellers to drive them in the desired direction but they are still greatly influenced by the wind direction and speed. Airships are slow. The Hindenburg tragically burst into flames when landing in the USA following a transatlantic flight. It was filled with the highly flammable gas, hydrogen. Modern airships are filled with non-flammable, Helium gas.

The first powered was first made by the Wright brothers in 1903. Early planes had two (biplane) and sometimes three rows of wings to generate the necessary lift. They were driven by piston engines and propellers. The jet engine was invented by Sir Frank Whittle and first flew from RAF Cranwell, Lincolnshire, UK in 1941. Jet engines are reliable, efficient and now power aircraft of all types.

Helium balloon investigation.

Each group has one helium balloon, cup and tape.

Young people first hold the helium balloon to experience the pull of the balloon's lift.

Young people attach the paper cup and add sand so that the balloon just floats level. The combined weight of the sand and the cup equals the amount of lift produced by the balloon. Too little sand and the balloon will rise as the upward lift is greater than the downward weight. Too much sand and the balloon will sink as the weight exceeds the lift.

Extension

Predict and test the lift produced by 2,3 or more balloons.

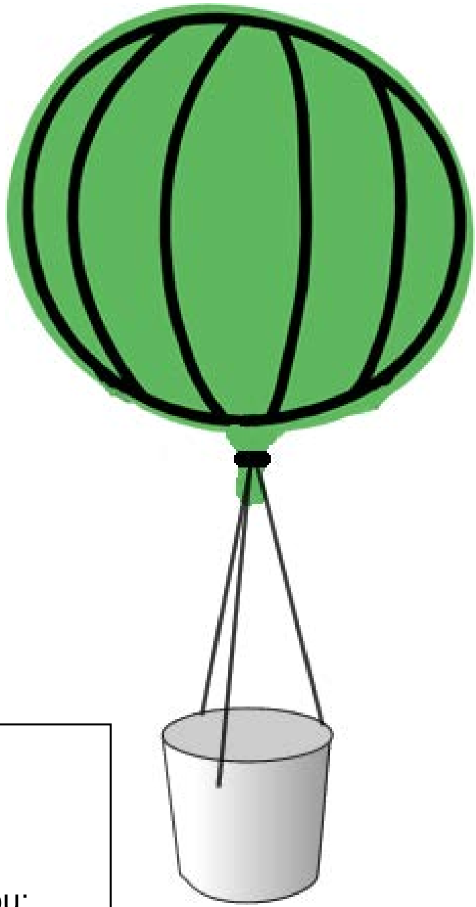
Have young people calculate how many balloons would be needed to lift them (needs scales to measure their weight).

Sea divers often inflate balloons under water to raise submerged objects. Have young people explain if the lift generated by a balloon (same size) in air is more or less than the lift generated in water. Can young people predict the lift caused by their balloon if it were submerged in water?

How much can a helium balloon lift?

You are going to see how much a helium-filled balloon can lift.

1. Hold onto the threads.
   Feel the balloon pulling up.
2. Get a small cup.
3. Use sticky tape to attach the threads from your balloon to the cup.
   You need to be able to put sand inside the cup.
4. Check to see that it still floats upwards.
5. Use a spoon to put a small amount of sand inside the cup.
6. Put just enough sand into the cup so that the balloon floats at the same level.
7. Use the scales to find the weight of the cup and sand.
   This equals the lift produced by the balloon.



- Draw a diagram that shows the forces acting on your balloon as it hovers level.
- Draw diagrams showing the forces on the balloon if you:

  a – added more sand. How would it move?
  b – took the sand out. How would it move?
- Predict how much two three or even four balloons tied together could lift.
  Try an investigation to test if your predictions are right.
- How many balloons would it take to lift you?

Activity 2: Airframe design and strong structures

The main structure of an aircraft is called its airframe. Early airframes were little more than wooden frameworks with limited strength. As knowledge of materials advanced, the use of aluminium and other alloys and composites have led to the production of stronger and more rigid airframes.

This activity challenges young people to build and test different structures.

Preparation

- Download the Airframe presentation
- Materials to build and test a model wing.

This can be simple or sophisticated, depending on the required outcomes. The items suggested below will allow a basic approach to be taken.

- Stiff card
- Paper
- Sticky tape
- Drinking straws
- Matchstick blanks (obtainable from craft shops)
- Masses and mass hanger
- Balance to weigh the wings
- Clamp to position the wing horizontally when being tested.

Activity notes

Use the presentation to illustrate how airframe construction has developed.

Early aeroplanes were little more than simple wood and metal frames with cables forming cross-members. Development of lightweight alloys allowed for designs incorporating geodetic frameworks. Modern composites, such as carbon fibre, used today allow for strong and lightweight structures to be made.

Design and make a wing.

Challenge young people to make a strong and light wing. The size of the wing and materials used can be varied depending on the desired learning outcome. This could include materials that can be shaped, such as balsa wood.

A suitable challenge could be to design and build a wing that is 20cm in length, 5cm in width and no more than 1cm thick.

A method of judging the design could include a combination of strength and lightness. This may be achieved by:

1. Measure the weight of the wing (w).

2. Find the maximum force the wing will support by hanging masses from its tip whilst clamped horizontally at its base (F).
3. Divide force by wing weight (F/w). The greater the number, the 'better' the wing.

Extension

Young people can be challenged to build wings that have an aerofoil cross-section. Wing frameworks can be covered in paper. How does the shape and thickness of the wing or its angle to the airflow influence its performance?

Measuring lift will be a tricky thing to achieve but it will challenge young peoples' ability to develop a suitable method. One possibility is to clamp the wing onto a stand and place both on a digital weighing balance. Blowing air over the wing should create lift and so reduce the apparent weight of the wing and stand.

It may be difficult to generate a measurable amount of lift, so this activity should be for young people who are likely to be engaged by the challenge of the task, rather than a method to gather data.

Activity 3: Propeller design

Many aeroplanes use propellers to develop their forward thrust. There are different designs and combinations of propeller blades.

Examples of propellers can be bought from design technology schools suppliers or model aircraft shops. These can be used to illustrate propeller structure and may also be used in the tests as a comparison with students' own designs.

Elastic-band-powered model aircraft are available from toy shops and model shops. These can be used to further demonstrate the use of propellers.

In this activity, it is suggested that young people build and test their own propellers using thin card (a template propeller blade is provided). More sophisticated designs could be achieved using a material that can be shaped, such as balsa wood.

Preparation

- Download Propellers presentation
- Room fan to illustrate a propeller (optional)
- Propeller blade template and activity sheet (can be found following these notes)
- Propeller blade outlines copied onto card
- Sticky tape
- Electric motor and power supply per group
- Cotton thread
- Suitable risk assessment

Activity Notes

Use the propeller presentation and a fan to illustrate how propellers work. In the presentation, point out the pitch of the various propeller blades on view and that propellers can consist of a different number of blades. The number depends on factors such as the size of the blade, their pitch, the power and maximum revolutions per minute of the engine.

Many modern propellers have variable pitch blades. With these, the engine runs at its optimum speed and the pitch of the blade is altered to vary the thrust.

Use the propeller design activity sheet.

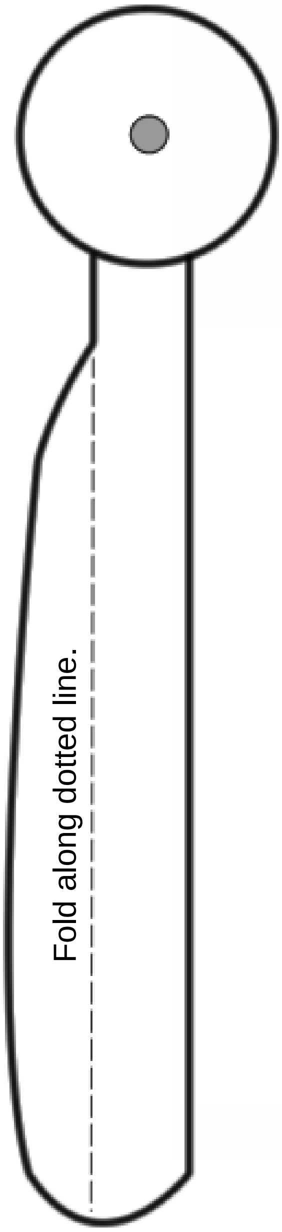
Young people make propellers with different numbers of blades and test them to see which generates the greatest flow of air. Young people can vary the speed of the motor to find the most efficient revolutions per minute.

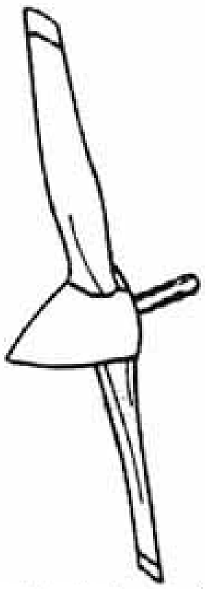
Extension

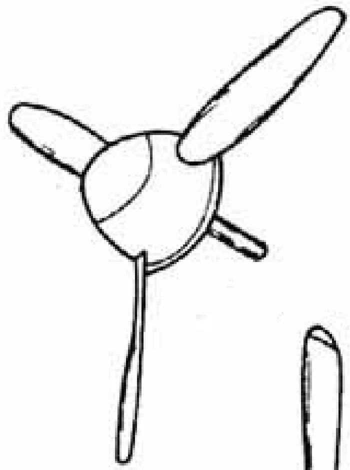
This activity can be easily extended to have young people look at factors such as:

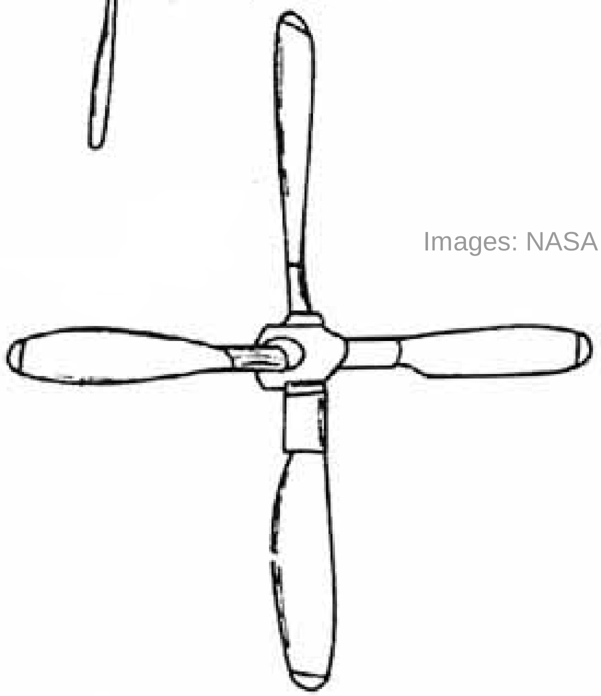
- how the pitch of the blade influences performance
- what are the effects of different blade lengths or widths
- how performance could be reliably measured
- different designs of blade, made with materials such as balsa wood

Propeller designs









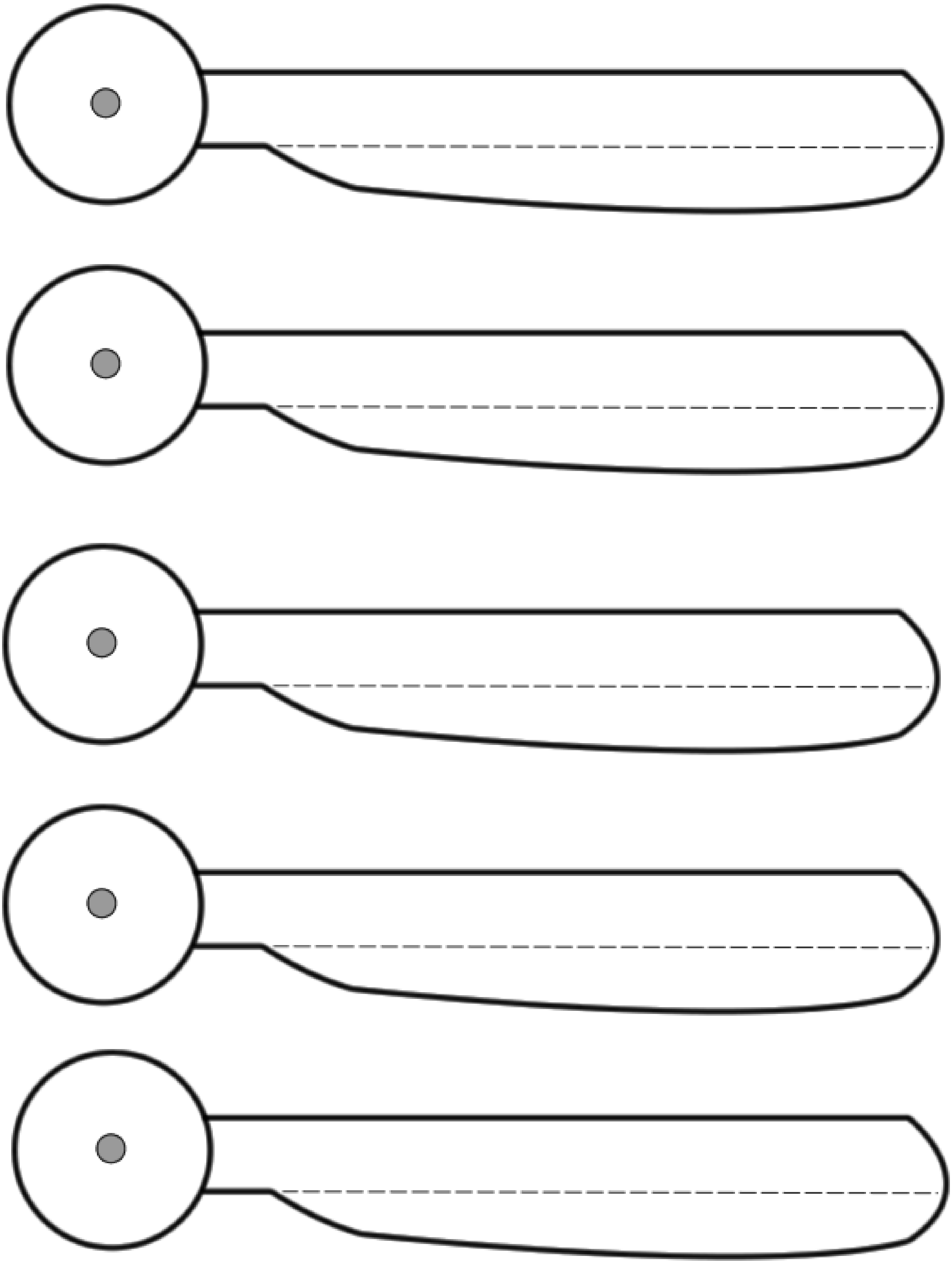
Images: NASA

How many blades are best?

1. Cut out the propeller blades on the piece of card.
2. Choose the number of blades you will test first.
3. Use sticky tape to join your propeller blades together at the centre.
4. Attach your propeller to an electric motor to test it.
   Hold a cotton thread in the airflow caused by your propeller to see how well it works.

- How many blades give the best propeller?
- Does the speed of the motor make a difference?
- Does the angle of the fold make a difference?
- How could you accurately measure the performance of your propeller?
- What other designs of blade could you make and test?

Propeller blades templates



Activity 4: Investigating Parachutes

This activity will require young people to test their parachutes by dropping them from a height. Suitable risk assessment and precautions should be taken to ensure this activity is done safely.

Young people make a sample parachute and then test their own designs. Flexible plastic from a carrier bag or tissue paper are suitable materials to make the parachutes. Sample templates are provided if young people require ideas for different shapes of canopy. These can be photocopied onto card and increased in size to test different sizes of canopies. However, young people should be encouraged to develop their own designs.

Preparation and Materials

- Parachute jump video from YouTube (RAF Falcons parachute display team – interview with team leader and footage of jump) http://www.youtube.com/user/RAFFalcons#p/a/u/0/_XDAq7guJ0s
- Parachute presentation
- Parachute investigation activity sheet, including range of parachute designs as required (follows these notes)
- Sheets of flexible plastic or tissue paper
- Sticky tape
- Light string
- Scissors
- Plasticine
- Suitable risk assessment

Activity Notes

Show the video to illustrate how a parachute works. The extra air resistance slows down the descent of the jumper. Discuss when and where parachutes are used (for sport, military aircraft but not on passenger aircraft).

Parachute presentation shows the early design concept by Leonardo da Vinci and development of functioning parachutes. Modern day parafoils act like wings. They contain two layers of fabric which form a wing-structure when inflated by air pressure. Parafoils are highly manoeuvrable, as shown by the Falcons display team video clip.

Parachutes can be made using a variety of designs and materials. Discuss why new parachute designs would first be tested using a model rather than a real person.

If plasticine is used, it will deform on impact with the ground. Young people may use this as a measure of the effectiveness of the parachute when investigating different parachute designs. Speed of fall or time to fall from a set height could also be measures of performance.

When investigating the parachute design, young people should devise a reliable and accurate test. Their investigations could look at:

- what weights can the parachutes be used with
- how the area of the parachute affects its rate of fall
- influence of the shape of the parachute
- holes or vents cut into the canopy
- number string threads used (attachment points) and stability of the parachute
- material used to make the parachute

<u>Extension</u>

Young people can video their tests to allow more detailed examination of how their parachutes perform.

Dataloggers can be incorporated, using motion sensors to measure the rate of fall.

Young people can investigate the use of multiple parachutes that could be used with heavier objects. For example when dropping equipment from aeroplanes.

Military, fast jets, have ejector seats. Young people could investigate the need for this technology as aircraft speeds increased and how ejector seats have developed over time.

Parachute Test

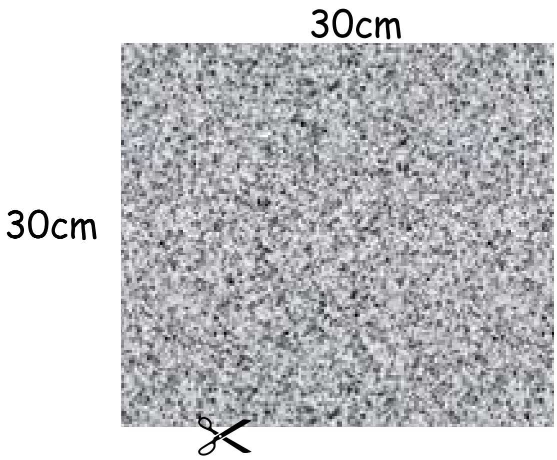
1. Cut out a 30cm x 30cm square of your parachute material.

2. Cut 4 pieces of string 30cm long.

3. Attach one end of each piece of string to each corner of your square.

4. Gather the other ends of the strings together. Tie them together.

5. Your model or weights can be attached to your parachute.



Parachute test

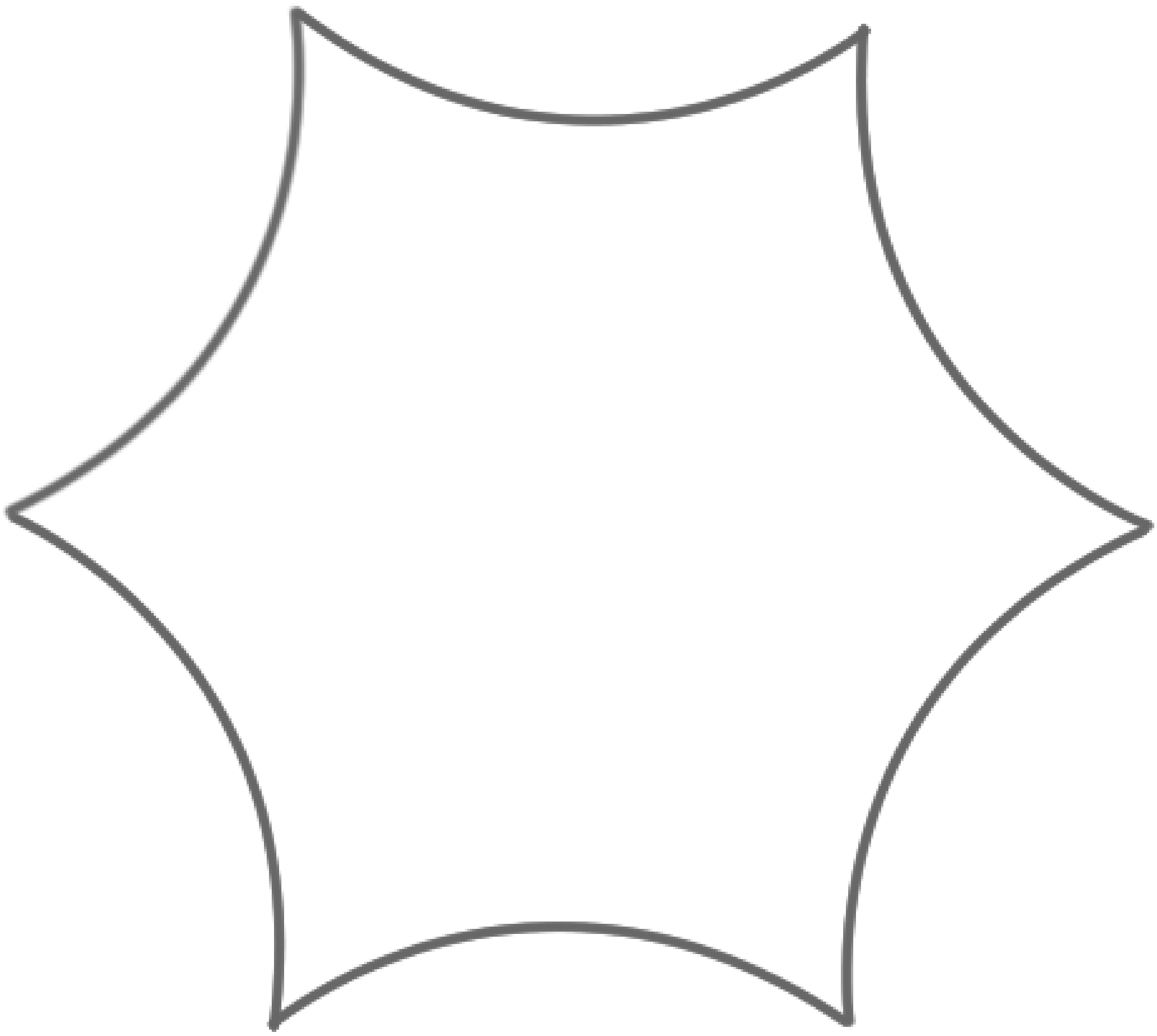
- Devise a test to measure reliably how well your parachute works. Make sure your test is safe to yourself and others.

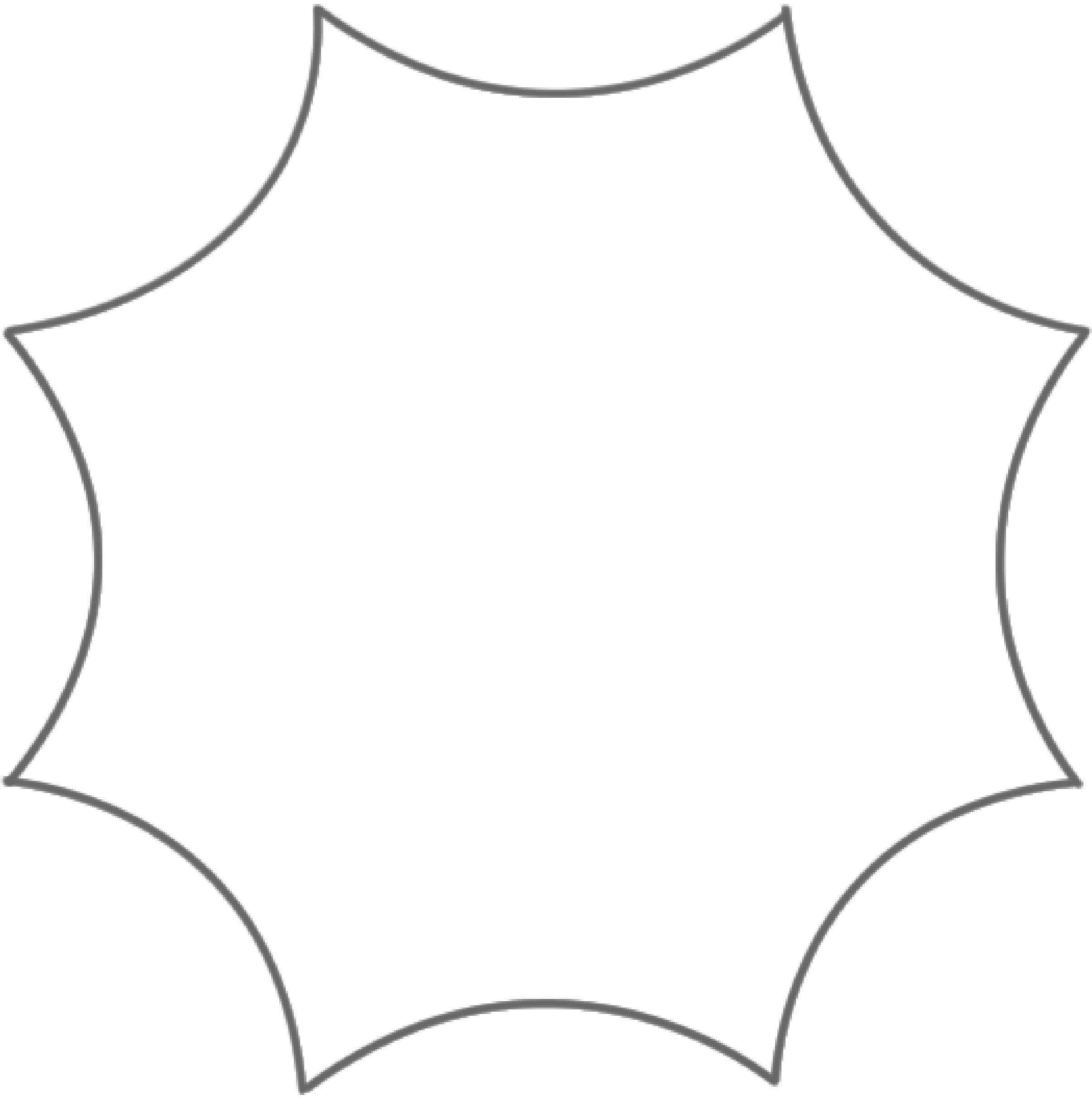
- Use your test to try other parachute designs.
  This could include:
  - shape
  - sizes
  - material

- Clearly describe your test.

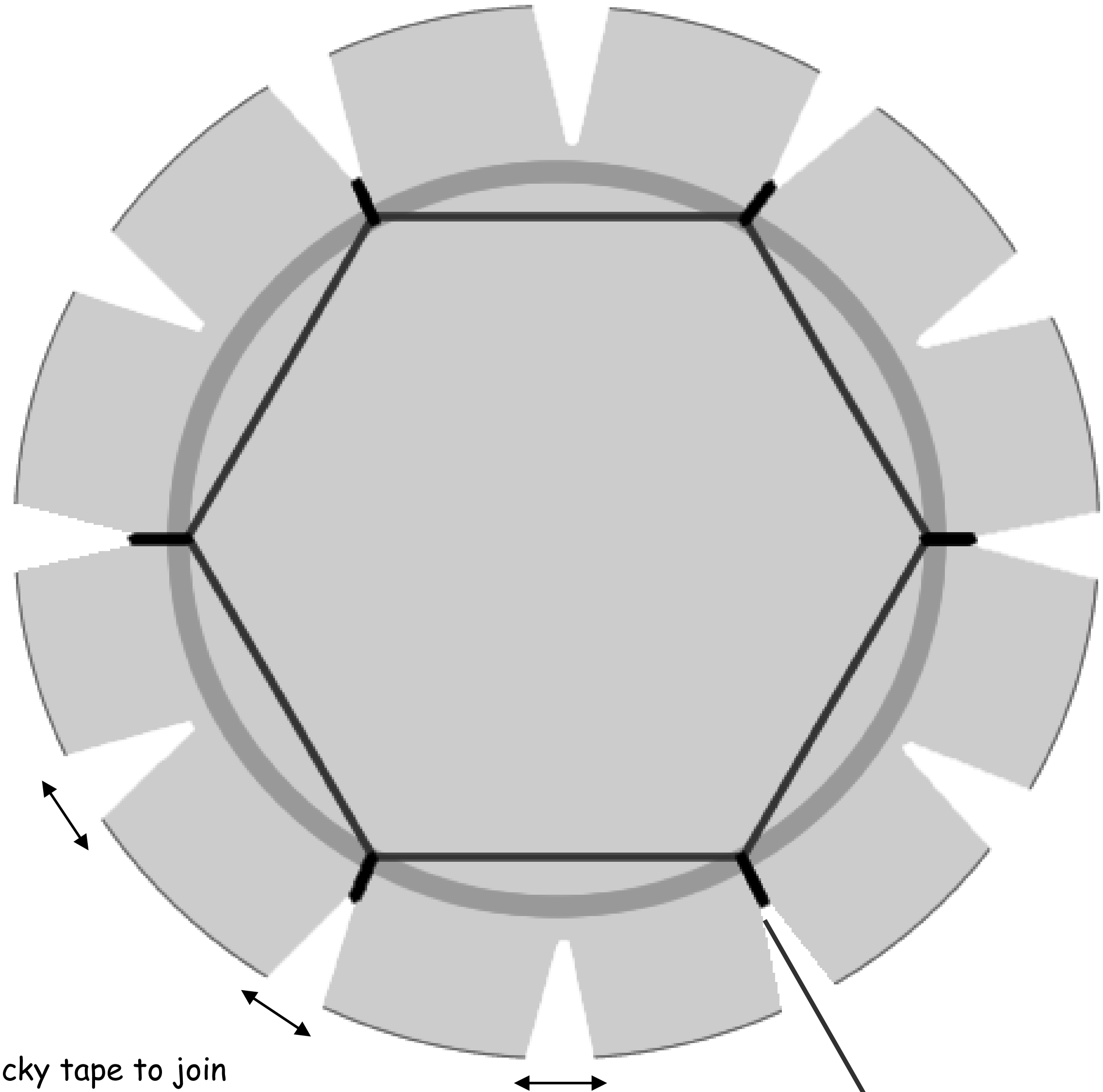
- Present your results and conclusions using tables and graphs.

Other shapes that could be tried as Parachute templates





Round saucer



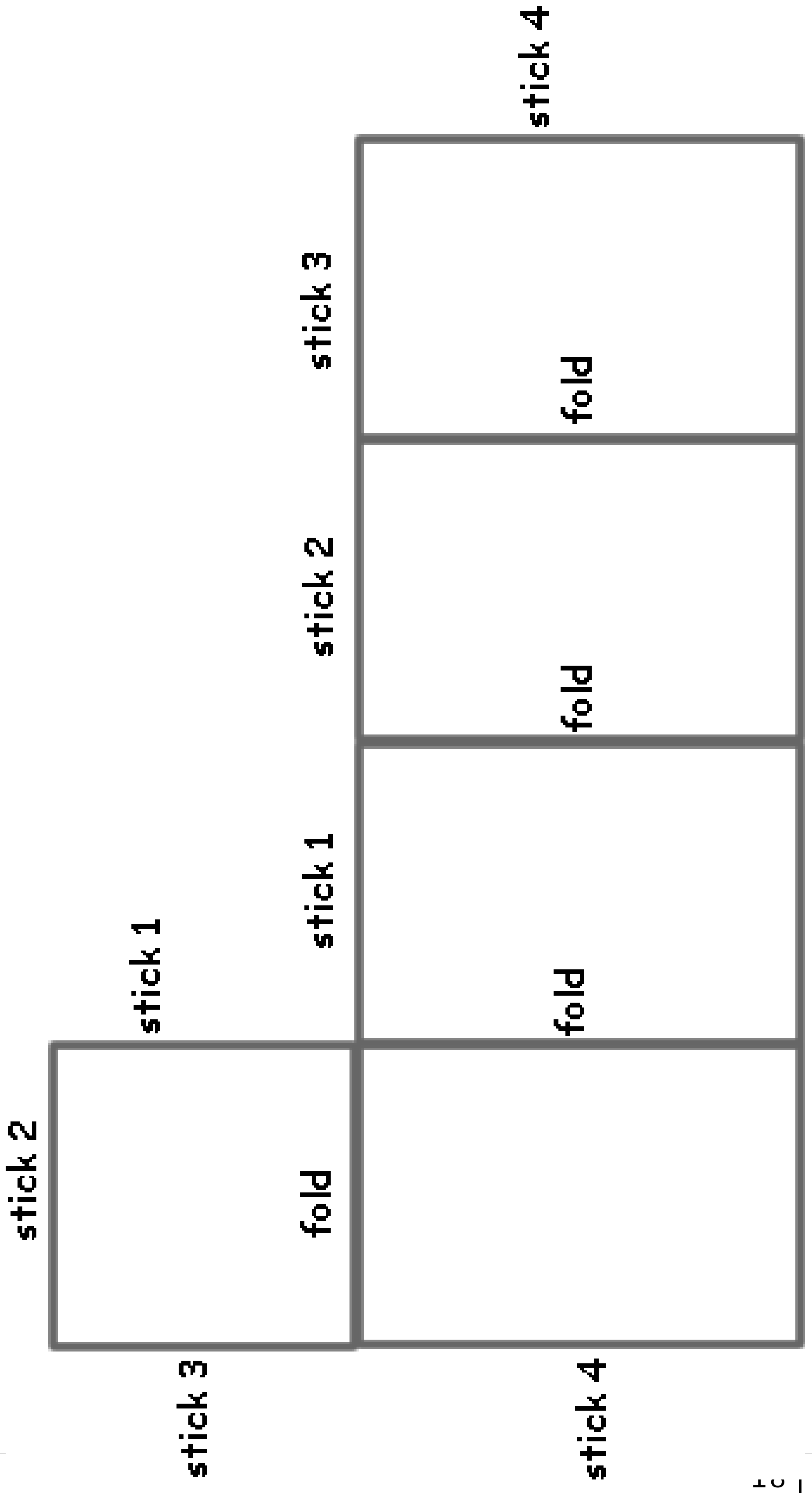
Use sticky tape to join the edges together.

Do this all the way round, so that the parachute forms a saucer shape.

String,

Use sticky tape to attach one piece of string to each of the six places shown with a

Cube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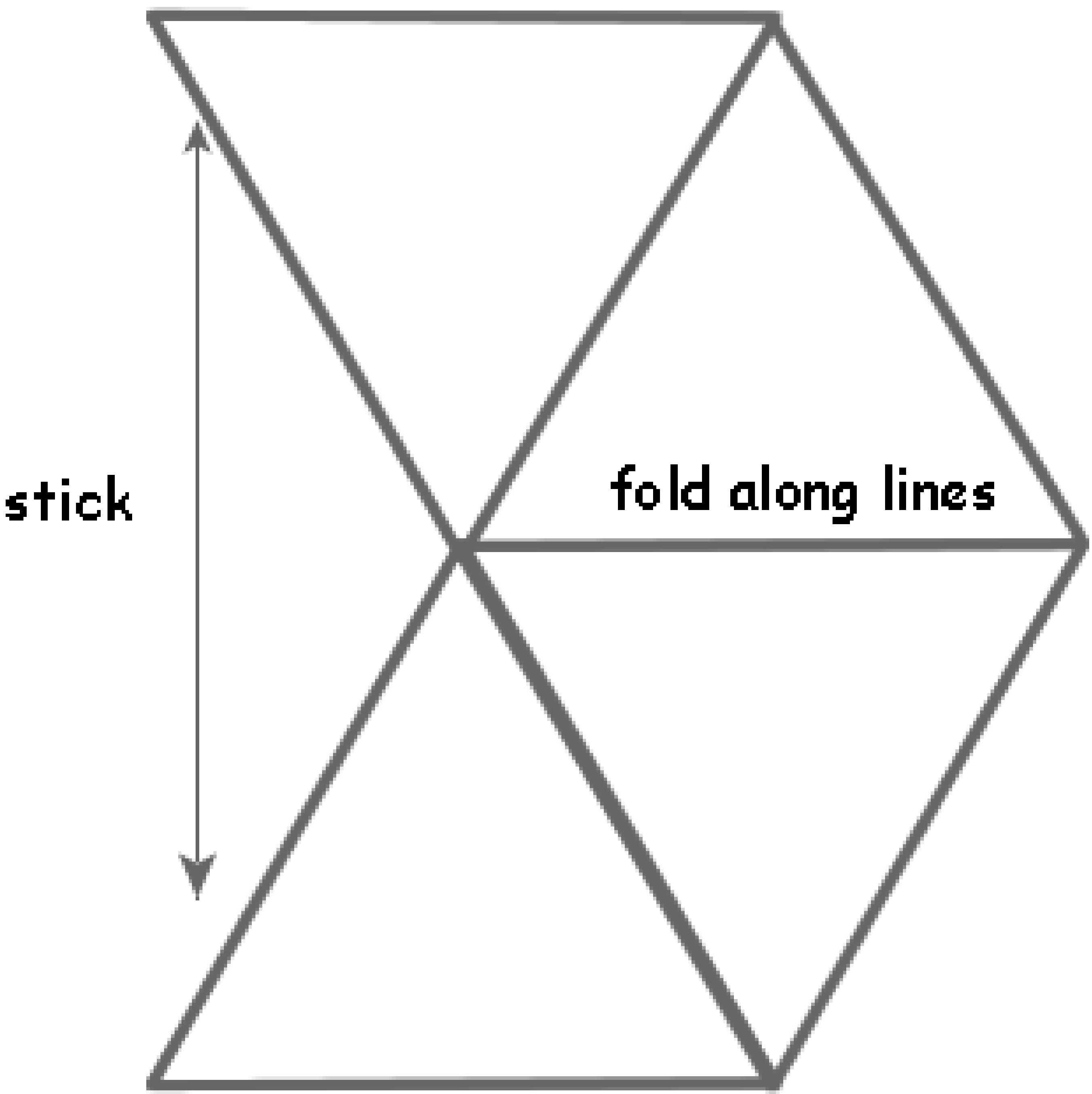
stick 3
fold
stick 2
fold
stick 1
fold
stick 1
stick 2
fold
stick 3
stick 4

Pyramid



Tube