Aeronautics

Aluminum Badge

Principles of Flight

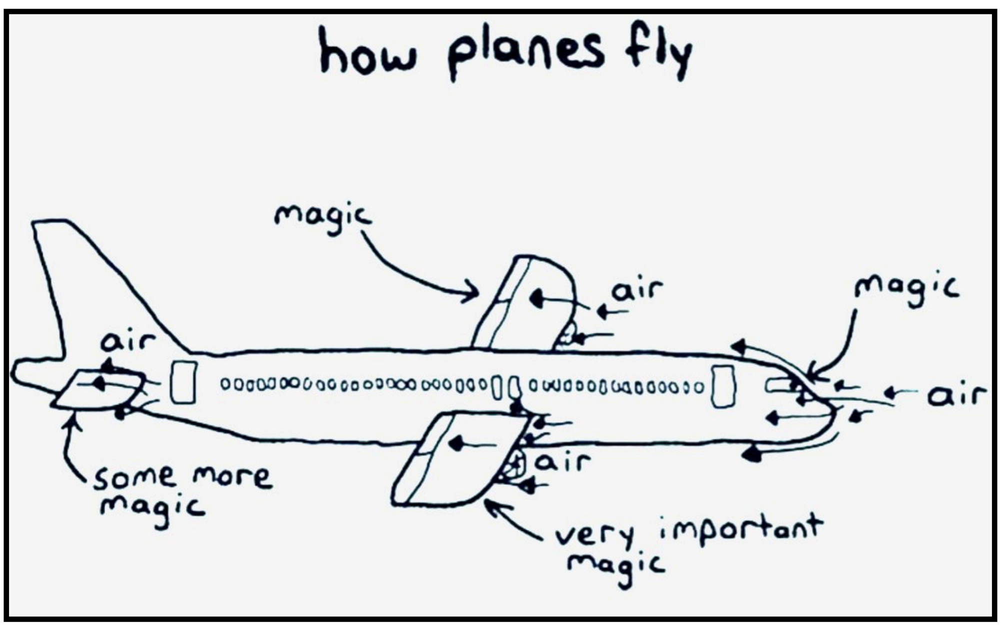
Facilitator Guide

National Aeronautics and
Space Administration

Adapted from

NASA Out-of-School Learning Network

Activities


how planes fly
magic
air
magic
air
air
some more magic
air
very important magic

Introduction

The following pages are taken from NASA's Aeronautics Module for Out-of-School Learning, with supplemental resources from the Civil Air Patrol, NASA, the Federal Aviation Association, and the Experimental Aircraft Association all of whom grant right of use for educational purposes.

The purpose of these modules is to engage students who are not particularly experienced with aviation or aerospace. Therefore, investigations should be activity based, with brief and simple application explanations. Ideally, instruction should take about five minutes, and always with visual support.

This handbook gives background information, links to extensions, and extended descriptions of activities. A student guide is necessary as well to connect your information to the student material.

Questions that can be asked throughout the module:

1. What does this tell us about how (air/gravity/wing shape/etc) works?
2. How does this help a plane fly?
3. What can we do to make this work better?
4. Is there a different way we could explore this concept?

You are encouraged to:

- Test each activity beforehand to anticipate any challenges that might come up.
- Take your time, especially with folding and assembly instructions.
- Show what you're doing AND explain. If possible, show from different perspectives to help visual learners.
- Don't feel you have to fill every second with words.
- Whenever possible, use correct terminology, but also feel free to make connections with comparisons or examples.
- Have fun! If you're excited about what you're doing, it shows and is

<u>Professional Skill Application</u>

Tips for discussing perseverance, organization, follow-through, open-mindedness, communcation, etc.

Video on [Four Forces of Flight]

Four Forces of Flight: this exploration uses five activities. The facilitator should introduce the forces first, demonstrating with plane model, taking no more than five minutes. The followup for each activity should refer back to the forces demonstrated.

Look at the opposing forces at work on a plane again. Gravity works against lift and drag works against thrust. Drag is the resistance of the airplane to forward motion. It wants to hold a plane back. You can feel a force pushing on you when you ride in a car and put your arm and hand out the window. As the car drives down the road, the force of the air pushes your arm backward. Your arm is creating drag.

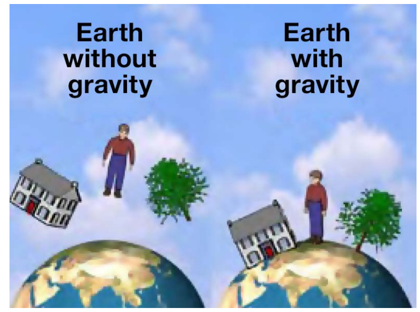
Drag is caused by air pushing against the airplane and is called air resistance. As an airplane moves through the air, it collides with air molecules that must go around the plane. The air “rubbing” against the metal of the plane is one way drag slows the airplane down. The shape of the plane can create more or less drag. A streamlined plane has less drag and moves through the air more easily because its shape allows the air to flow easily over it. A bulky shaped plane has more drag because air cannot flow easily over it.

Lift

Lift is the force that holds the airplane in the air and directly opposes the weight of an airplane. Lift is generated by every part of the airplane, but most of the lift is generated by the wings. Lift is a mechanical aerodynamic force produced by the motion of the airplane through the air. Because lift is a force, it is a vector quantity, having both a magnitude and a direction associated with it. The magnitude of the lift depends on several factors including the shape, size, and velocity of the aircraft. Lift acts through the center of pressure of the object and is directed perpendicular to the flow direction.

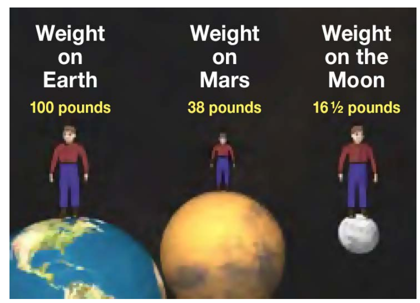
The Pull of Gravity

A force is a push or a pull. Gravity is the natural force that pulls objects toward Earth. If the Earth did not have gravity, we would float into space. Some people compare Earth's gravity to a huge magnet. Unlike a magnet that attracts only iron, Earth's gravity attracts all objects to the ground. Gravity is also the force that gives objects weight. If the Earth had no gravity, we would have no weight.



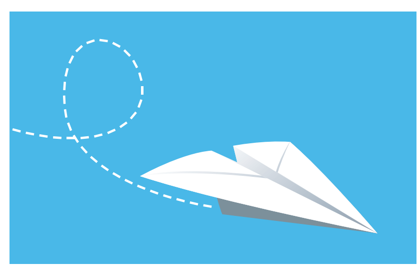
All matter has gravity—even you, but you do not have enough mass to produce enough pull. Huge masses like the Earth have a strong pull. In fact, the more mass an object has, the stronger the pull. Earth's pull of gravity is so strong that it can hold the Moon in orbit. The Sun's pull of gravity is even stronger and holds all planets in orbit.

Gravity gives everything weight. An object's weight is a measure of the force of Earth's gravity on it. The greater the force of gravity on an object, the more it weighs. Sometimes this is hard to understand. No matter where we are in the universe, we still have the same mass, but we will not have the same weight. Remember, the more mass an object has, the stronger the pull. Earth has 6 times the mass of the Moon. So, its gravity is 6 times greater than the Moon. If you weigh 100 pounds (45.3 kilograms) on the Earth, you will weigh about 16.5 pounds (7.5 kilograms) on the Moon.



Thrust

Wings give an airplane lift, but wings cannot make a plane go forward. Thrust is the force that moves an airplane forward. Thrust affects how fast and how far you go. When you throw a paper airplane forward, you are providing the thrust. Birds flap their wings to create thrust.



In airplanes thrust is usually provided with propellers or a jet engine. When planes use propellers, engines (usually piston engines) turn the propellers at very high speeds. A propeller plane has a set of two or more small rotating wings. Like a fan, the propellers pull air in and push it out in the opposite direction. Jet airplanes use jet engines to pull air in and mix it with fuel. Then the burning gas goes out the back and pushes the plane forward. Newton's Third Law of Motion states, "For every action there is an equal and opposite reaction." In both kinds of engines, air is pulled in and then pushed out in the opposite direction. When the air pushes backward, the plane is pushed forward.

The four forces of flight—gravity, lift, drag, and thrust—are properties that affect how objects move through the air. The forces cause objects to move up or down and faster or slower. The balance of these forces changes how objects move through the air.

Materials

Student Handout, pencil

Paper Shape (gravity)
- Notebook paper
- 1 golf ball

Chin Ups (lift)
- 1 piece of 6- by 2-in. paper

Paper Pull (lift)
- 2 strips of 2- by 12-in. paper

Flow Away (thrust)
- Strong plastic cup (10 to 12 ounce size)
- 3 pieces of 25.4-cm (10-in.) long string
- Container of water
- Dishpan
- Hole punch
- Scissors
- Masking tape

It's a Drag (drag)
- One tall clear container with a wide mouth or sink
- Water
- Modeling clay

Professional Skill Application

Take time between each exploration to clean up. Explain why this is important from a science perspective.

<u>Wind in Your Socks</u>

Materials

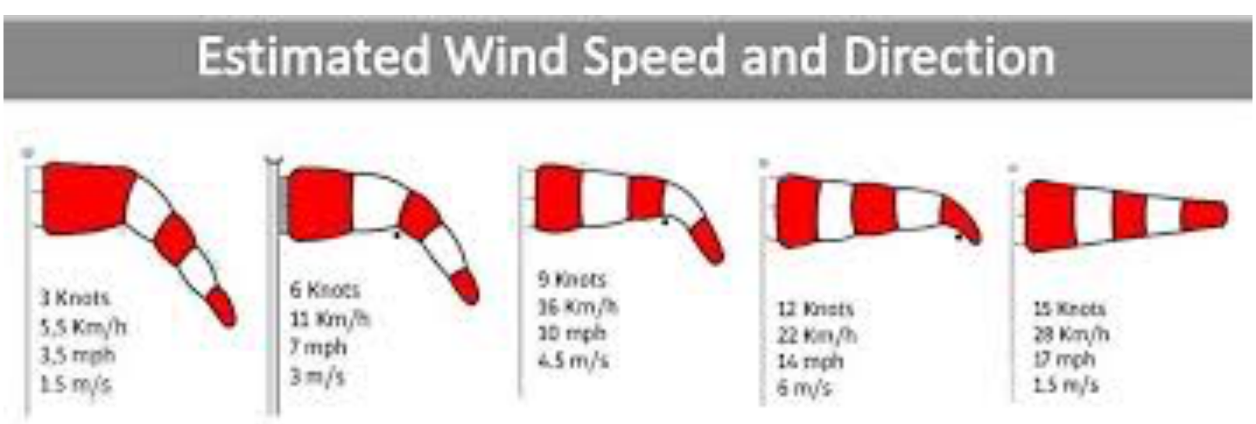
- 2 x 11 in. cardstock
- Sheet tissue paper
- Glue
- Transparent tape
- Scissors
- Hole punch
- Paper clip
- Metric ruler
- 1.2-m kite string
- Compass
- Large boxes or other shapes to represent land masses
- Student handouts

Background

A wind sock is a type of kite that is used to detect wind direction. It is a tapered tube made from flexible material or cloth that is held open at one end by a stiff ring. Wind blows into the larger open end and through the tube, and causes the narrow end to point in the same direction. Brightly colored wind socks are used at airports to help pilots determine the wind direction along the ground, and meteorologists use wind direction to help predict the weather.

<u>Professional Skill Application</u>

The wind sock will need something to hang from that allows it to catch the wind. This is a good chance to discuss problem-solving. A fence post, mop handle, large stick, even a ruler or pencil that can be held above the holder's head will work. Sometimes we find solutions that don't seem obvious, but end up being great.
ALSO, if you've not worked with students in grades 4-6, their sense of humor will lead them to snicker at the windsock images. It happens.



Procedure

Step 1

Cut the tissue paper into 28- by 28-cm squares before beginning the activity for each student making a wind sock.

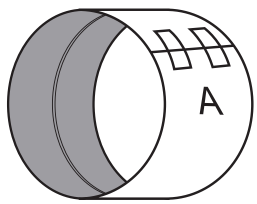
Step 2

Explain to students that they will be making a wind sock that will demonstrate wind direction and relative speed. Explain that winds are named for the directions from which they blow (south, north, east, and west). For example, a north wind blows from a northerly direction.

Step 3

Make a loop of the cardstock and tape the ends together. Mark the letter A on the outside (Fig. 1).

Figure 1



Step 4

Draw a 4-cm line from one edge across the tissue paper. Mark the 4- by 28-cm area with the letter B (Fig. 2).

Step 5

Beginning along one end of the line drawn in Step 5 above, measure and mark a point 3 cm from the edge. Continue marking points along the edge every 3 cm as shown in Figure 2.

Step 6

Repeat Step 6 to mark points along the opposite end of the tissue paper.

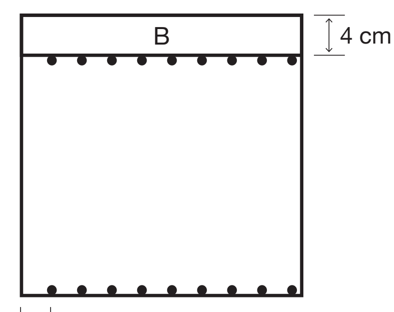
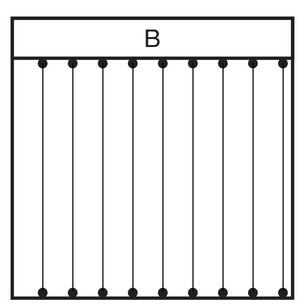


Figure 2

Step 7

Using the points, draw a series of lines on the tissue paper. With scissors, cut along these lines to make strips (Fig. 3).



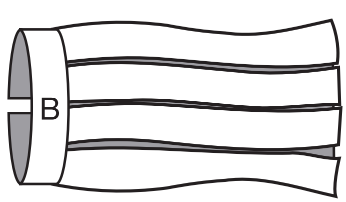


Figure 3

Step 8

Glue edge B of tissue paper to edge A of the loop strip made in step 4 (Fig. 4). Allow time for the glue to dry.

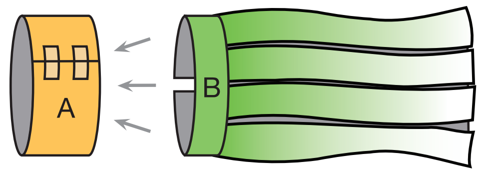


Figure 4

Step 9

Punch three equally spaced holes around the paper ring as shown in Figure 5.
Note: hole reinforcements can be used.

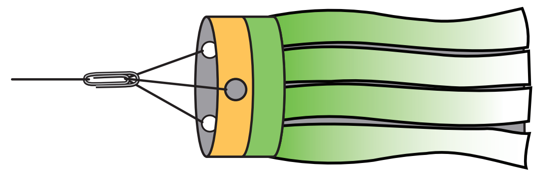


Figure 5

Step 10

Cut three pieces of 30-cm-long string. Tie one end of each string to the holes in the wind sock.

Step 11

Tie the 3 loose ends of the string to a single paper clip. Add another 30-cm piece of string to the paper clip.

Step 12

Test the wind sock by holding the single string in front of a fan. The fan simulates the wind, and the wind sock should point in the direction the wind flows.

Step 13

Explain to students that wind is affected by geographical elements. When wind interacts with mountain regions it travels up the side of the mountain on the windward side and over the top and down on the leeward side. Changes in wind direction are very important to pilots because different land masses have different effects on wind speeds and direction.

Step 14

Have students place various sized objects between their fan and wind socks to demonstrate how land masses can affect winds and record their observations.

Step 15

Tape the wind sock to a broom or stick as shown in Figure 6 and take it outside. This wind sock speed gauge is a way to measure general speeds (not actual speeds). Use the compass to mark north, south, east, and west below the wind sock to help determine wind direction.

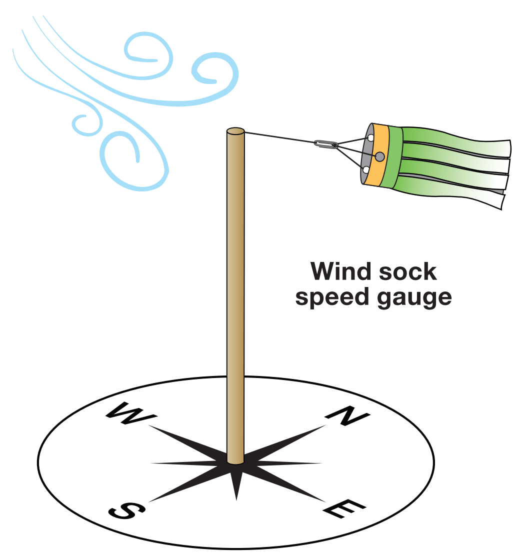


Figure 6

Overcoming Gravity

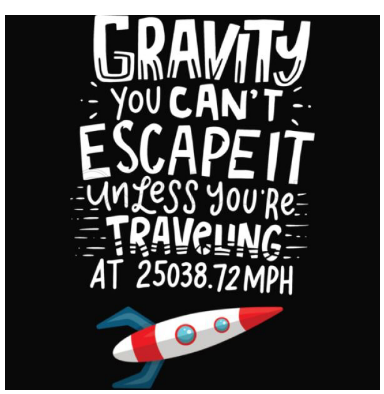
Materials

- Round balloon
- Masking tape
- Clothespin
- Straw
- Small paper cup (3-ounce size)
- String, long enough to reach from the floor to the ceiling
- Scissors
- Paper clips
- Hole punch
- Student handouts
- Pencil

Professional Skill Application
Discuss safety in attaching string to the ceiling. Location is an important factor as well. Take time to determine a place that is out of the way of family members, doors, etc.

This activity has a lot of parts to manage. It's not unlikely that the cup will crack while punching the holes in the rim. This does not ruin a project, there are solutions. Discuss ways to adapt an exploration to still work despite setbacks.

Interactive chart: How much would you weigh on other planets?



Procedure

Step 1

Before the students are ready to test, introduce the lesson by reviewing the background material. Note: a doorframe can be used instead of the ceiling to test their devices.

Step 2

Divide the students into groups of three or four.

Step 3

Measure the distance from the ceiling to the floor. Note you will be measuring the distance from the floor to how high your balloon rises. Try to do this step close to a wall or door so you can secure a tape measure near the string.

Step 4

Add 15 cm to the measurement from the ceiling to the floor and cut a piece of string for that amount. Tape or tie the string to a spot on the ceiling.

Step 5

Thread the string through the straw. Stretch the string tight and tape it to the floor.

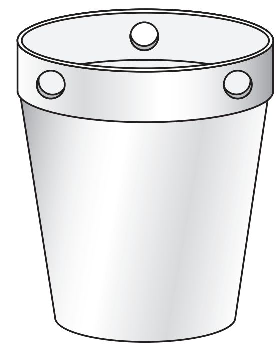


Figure 1

Step 6

Use the hole punch to make three holes around the top of the cup. Space the holes evenly as shown in Figure 1.

Step 7

Cut three pieces of 30-cm-long string. Tie one string to each hole in the cup.

Step 8

Use the balloon pump to blow the balloon up and count the number of pumps it takes. Use a clothespin to keep the air from escaping until you are ready to release it.

Step 9

Tape the other end of the strings to the balloon so that it looks like a hot air balloon with a basket under it.

Step 10

Tape the balloon to the straw as shown in Figure 2.

Step 11

Lower the balloon to the floor, count down, and let go of the clothespin.

Step 12

Mark how high the top of the balloon rose on the string. Measure and record data on your student handout.

Step 13

Blow up the balloon about the same size as before and add five paper clips in the basket. Launch the balloon and record the height.

Step 14

Repeat Steps 7 to 11 and add five more paper clips each time until the balloon will no longer launch.

Step 15

Analyze data and graph your results in the student handout.

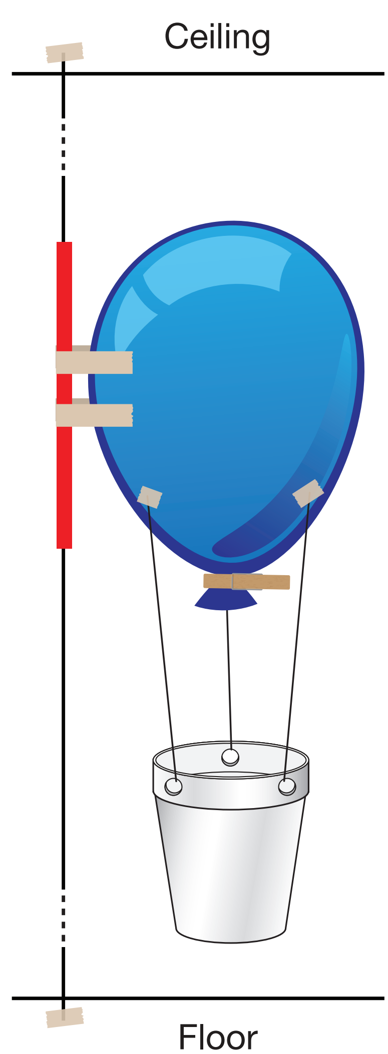


Figure 2

Ring Wing

Materials

- 8.5- by 11-in. sheets of paper
- Tape
- Ruler or tape measure
- Additional types or sizes of paper for experimentation
- Student handouts

Background

NASA's Aeronautics Research Mission Directorate is developing technologies that will make future aircraft more economical and efficient than today's aircraft. Aeronautics research takes on many forms, including various wing shapes and configurations.

One revolutionary wing configuration, called the blended wing body, or BWB, has a thick airfoil-shaped fuselage, or main body section that combines the engines, wings, and body into a single lifting surface. The BWB can carry as many as 800 passengers over 7,000 miles at an approximate cruise speed of 560 mph. Compared with today's airliners, the BWB would reduce fuel consumption, harmful emissions, operating costs, and noise levels.

Another research concept used for personal aircraft utilizes ring wing technology, which allows aircraft to take off and land in a variety of locations. Airplanes of the future may look very different from those of today.

Professional Skill Application

Consider where the model will fly. Be sure to avoid breakable objects and people. If possible, go outside, away from power lines.
Sometimes more force isn't the solution. This model flies best with a gentle flick of the wrist rather than flinging it with full force. It might take some trial and error to find what works best.

Procedure

Step 1

Discuss with students that NASA engineers are developing new and interesting wing designs, including one called the ring wing. Let students know that they will build a ring wing glider and redesign the glider to make the best design possible. As a group, they will decide what design factors will be used to determine the best design.

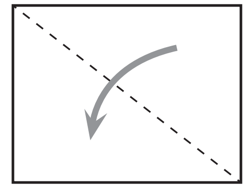
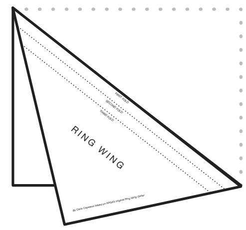


Figure 1



Step 2

Fold a piece of 8.5- by 11-in. paper diagonally as shown in Figure 1.

Step 3

Make a 1/2-in. fold along the previously folded edge and another 1/2-in. fold as shown in Figure 2.

Step 4

Curl the ends of the paper to make a ring and tuck one end into the fold of the other. Use tape to hold the ring shape together (Fig. 3).

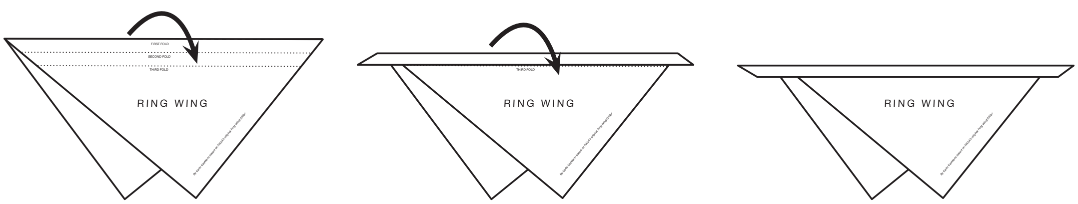


Figure 2

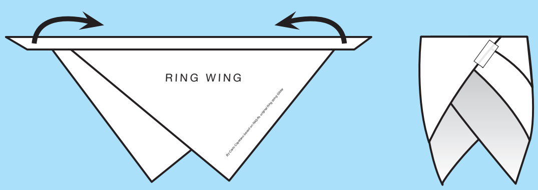
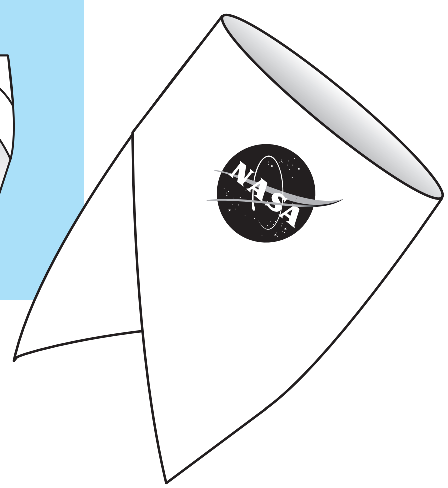


Figure 3



Step 5

To fly the ring wing glider, gently grasp the V shape between the two points with your thumb and index finger.

Step 6

Raise your arm back over your head and toss the glider forward lightly. Note the folds in the paper make the front end heavy and the back end light. Curling the ends to make a ring changes the shape of the wing and improves the glider's flight performance. Students should record the data in their student handout.

Step 7

Bring the students together and discuss what determines the best flight. Is it distance? Hang time? Loops? Once criteria is determined, have students embark on creating the best/better ring wing glider.

Sled Kite

Materials

- Template
- Drinking straws
- Transparent tape
- Scissors
- String
- Ruler
- Single-hole paper punch
- Paper clip
- Selection of paper
  (crepe, tissue, or newspaper)
- Student handouts

Background

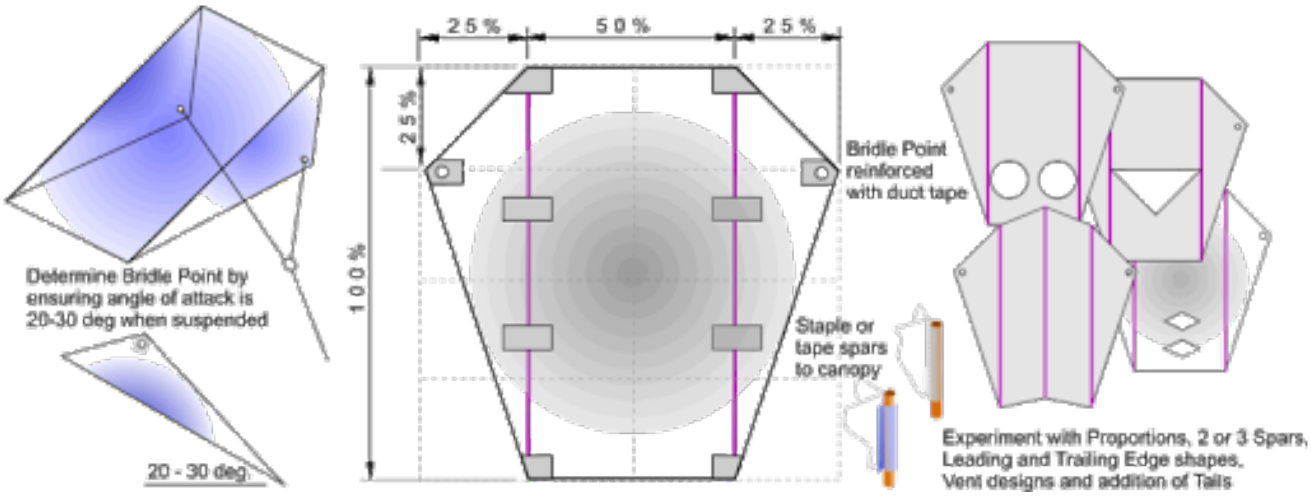
The sled kite in this activity is based on a type of airfoil called a parawing. Like any wing shape, movement of air over the parawing generates a lifting force. (Parasails, parafoils, and paragliders are similar devices.)

NASA's Paraglider Research Vehicle (Paresev) was the first flight vehicle to use the parawing design by Francis Regallo. NASA built, flew, and evaluated the glider during the early 1960s to evaluate the concept and to determine its suitability to replace the parachute landing system on the Gemini spacecraft. Although the parawing was never used on a spacecraft,

it revolutionized the sport of hang gliding, which uses parawings to glide from cliffs or mountain tops.

Kites are made from many different shapes, sizes, and colors. The sled kite in this activity is made from a piece of cloth or paper and two drinking straws. The straws are attached on opposite sides of the cloth or paper and are parallel to each other. This arrangement shapes the kite like a sled when it catches the air. The straws are attached toward one end of the kite, which causes the opposite end to hang downward, and stabilizes the kite during flight.

SLED KITE



Exploration Questions:
1. What did your sled kite do when you walked with it?
2. What did your sled kite do when you ran with it?
3. Add a tail to your kite. Predict what will happen when you walk or run with it now.
4. Describe how adding a tail to your kite affected the way it flew.
5. Shorten the tail. Predict how that will affect the flight.
6. What did you observe? What can you generalize about adding a tail?

<u>Professional Skill Application</u>
While decorations are not necessary for the kite's flying abilities, visual design has always been an important part of development. Take time to decorate the kite.

As the kite flies, notice how it behaves. Are there any problems? What could be done to solve them? Adding something? Taking something away?

Right Flight

- Materials
- Styrofoam plate with template
- Plastic knife
- Toothpicks
- Binder clips
- Paper clip
- Markers
- Student handouts

Background

Early Flights Wright Brothers Flight

On December 17, 1903, two brothers named Wilbur and Orville Wright became the first people to fly a controllable, powered airplane. The Wright brothers unraveled the mysteries of flight by building and experimenting with lots of model gliders. Gliders are airplanes without motors or a power source.

Building and flying model gliders helped the Wright brothers learn and understand the importance of weight and balance in airplanes. If the weight in the airplane is not positioned properly, the airplane will not fly. For example, too much weight in the front (nose) will cause the airplane to dive toward the ground. The precise balance of a model glider can be determined by varying the location of small weights.

Wilbur and Orville also learned that the design of an airplane was very important. Their experiments with different designs showed that airplanes fly best when the wings, fuselage, and tail were designed and balanced to interact with each other. The Wright Flyer was the first airplane to complete a controlled takeoff and landing.

To manage flight direction, airplanes use control surfaces. Elevators on airplanes, like tail wings or stabilizers, are flight control surfaces that make the nose of the airplane pitch up and down. Rudders move the nose left and right. The Wright Flyer used a technique called wing warping to begin a turn. On modern airplanes, ailerons are used to roll the airplane into a turn.

NASA uses model airplanes to develop new concepts, create new designs, and test ideas in aviation. Some models fly in the air using remote control while others are tested in wind tunnels. Information learned from models is an important part of NASA's aeronautical research programs. NASA's aeronautical research goals are to make airplanes fly safer, perform better, and more efficiently.

Wright Flyer Right Flight Glider

Right Flight

Build an FPG-9 (**F**oam **P**late **G**lider, 9 inch)

1. Cut the foam template out by following the pen lines.

Important Note – Cut along the dotted line to separate the tail from the wing of the FPG-9. It works better to cut from the outside of the plate towards the center of the plate. Do not try to turn your scissors to cut sharp corners. When cutting out the slots, make them only as wide as the thickness of the foam plate. If the slots are cut too wide the pieces of the plane will not fit together snugly.

2. The wing and the tail each have slits drawn on them. Make a cut along each of these lines as drawn.

3. To attach the tail to the wing by sliding the slots together. Use two small pieces of tape to secure the bottom of the tail to the bottom of the wing. Ensure the tail is perpendicular to the wing before adding the tape.

    3a. Fly your glider. by gently tossing it forward. Notice how far it travels and where it goes. Describe its flight.

4.One way to help the glider fly well, tape a penny just behind the square tab. Fold the tab back over the penny and tape it down to secure the coin.

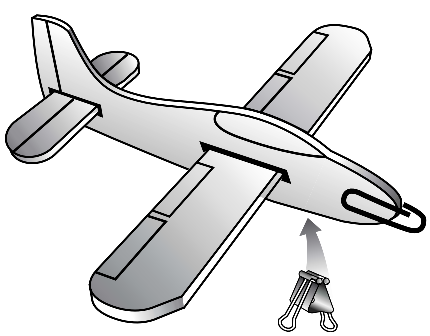
4a. Fly your glider. Notice how far it travels and where it goes. Describe its flight.

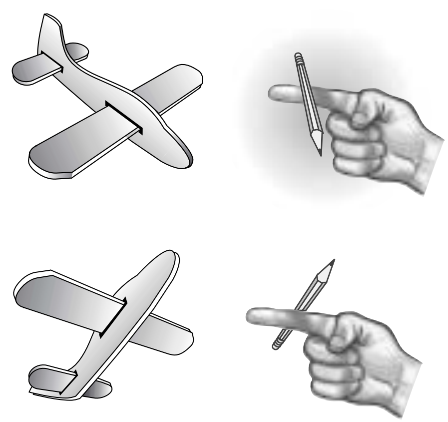
5. Bend the elevons on the wing upward and adjust the rudder on the vertical fin.

5a. Fly your glider. Notice how far it travels and where it goes. Describe its flight. Adjust elevons and rudder in different configurations.

5b.Once it flies reasonably straight ahead and glides well, try throwing it hard with the nose of the glider pointed a little above the horizon. The FPG-9 should perform a big loop and have enough speed for a glide of 20 – 25 feet after the loop.

6. Use the binder clip as added weight underneath the glider. Explore how changing the center of gravity affects flight.





Aircraft weight is balanced like
a pencil is balanced on your finger.

Professional Skill Application

Personal challenge: https://www.scientificamerican.com/article/balancing-challenges/

Keeping records is important to scientific research to remember from one trial to another what worked and what didn't. Taking notes for phone numbers, shopping lists, due dates are all ways to stay organized and informed.

Rotor Motor

Materials

- Template printed on plain white paper
- Student handout
- Scissors
- Pencil or marker
- Ladder or stable platform, at least 4 feet high
- Stopwatch (if available, most cell phones come with an app)

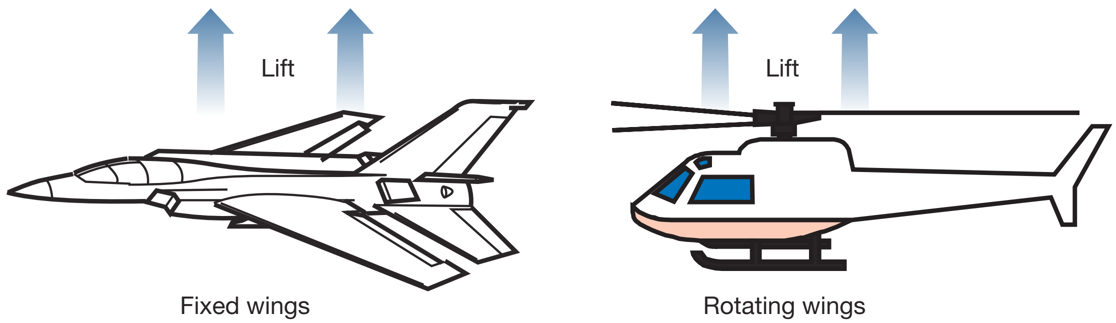
Background

Air moves faster over the top of an airplane wing than it does under the wing. Because the faster moving air produces less pressure, there is relatively less pressure over the wing than under it. This is how lift is produced. To fly, birds and insects use a flapping motion to move the air over and around their wing surfaces. Airplane wings are attached to the fuselage in a fixed position. Lift is generated by the entire wing moving through the air.

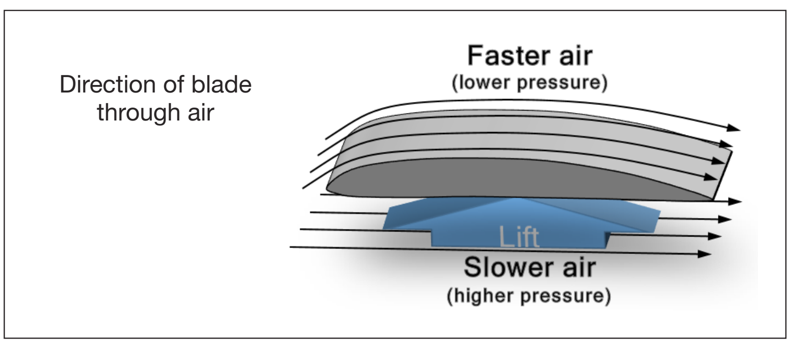
Because helicopters are rotary wing aircraft, lift is generated when their blades rotate through the air. Lift is produced by the pressure differences caused by the shape of rotating blades; this is the same way lift is produced by aircraft wings. The rapidly moving air over the top of the blade creates low pressure while the slower moving air beneath the blade creates higher pressure. Higher pressure under the rotor blades creates lift making the aircraft rise up.

Because paper models do not have motors, they only have one source of lift. As paper models fall, they spin like the rotor blades of a helicopter. Because there is no engine to produce upward movement, the paper model will not fly upward, but the spin will reduce the rate of fall by producing lift, resisting the force of gravity.

NASA builds and tests experimental helicopters and tiltrotor airplanes to achieve lower noise levels and greater fuel efficiency. NASA tests their models in wind tunnels at Langley, Glenn, and Ames Research Centers.



Cross section of aircraft wing, or a rotor blade



Professional Skill Application

Ingenuity means taking what you know and looking for new solutions. Just like all the explorations in this module, the design of the rotor is pretty basic, but there are lots of ways to customize it.

National Air and Space Museum Explore Flight Like the Wright Brothers to create a virtual airplane design in the Wright Brothers' workshop.