BUILD AND TEST AIRFOILS

You have been learning about the Wright Brothers and their decision to measure the lift and drag on their various airfoils using a simple wind tunnel. They built airfoils, tested them, recognized areas for improvement, and then re-tested the designs. They were the first to use this process to systematically test their theories and design their gliders and airplanes.

WHAT IS AN AIRFOIL?

An airfoil is a wing shape that when moved through a fluid (air) produces an aerodynamic force. Airfoils are used as the basic form of the wings, fins, and horizontal stabilizers of most aircraft.

1. Write the definition of the following:

1a. Trailing Edge *Last place air makes contact with the airfoil.*

1b. Leading Edge *First place air makes contact with the airfoil.*

1c. Chord *Straight line that connects the leading edge (most forward point) to the trailing edge (most rear point).*

1d. Angle of Attack *Angle between the chord line and the relative wind flow. If the leading edge of the airfoil is higher than the trailing edge, then the airfoil has a positive angle of attack.*

1e. Thickness *Maximum distance between the upper and lower wing surfaces.*

1f. Mean Camber *The line drawn between the leading and trailing edge so that the distances between the upper and lower surfaces are equal.*

1g. Max Camber *Measured where there is maximum distance between the chord line and the mean camber line.*

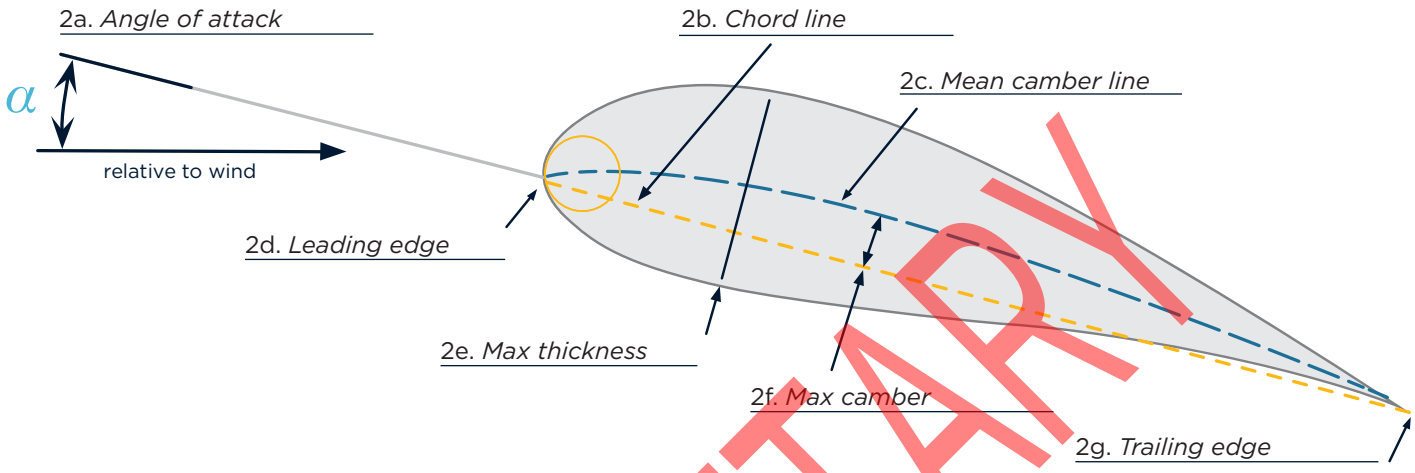
1h. Symmetrical Airfoil *The upper and lower surfaces of the airfoil are identical. The chord line and the mean camber line directly overlap one another.*

1i. Asymmetrical Airfoil *The upper surface is more curved. The mean camber line is above the chord line.*

1j. Planform *The shape of the airfoil when viewing from above.*

1k. Span *The length between the ends of the wingtips.*

2. Label the parts of the airfoil



Characteristics of an airfoil that influence lift

3. Curved surfaces produce more lift than *flat* surfaces.

4. Curved surfaces also produce more drag. They learned that a curved surface with a *camber* is ideal.

5. Airfoils with the curve closer to the *leading edge* produce more lift.

6. Airfoils that are *thin* and *long* create more lift.

7. *Cambered* airfoils create lift at zero angle of attack.

BUILD AND TEST

In small groups, you will build two airfoils out of foam board. Each group will build one symmetrical airfoil of a given chord and span, and one asymmetrical airfoil of a given chord and span. You will test the airfoils in your new wind tunnel to determine which airfoil creates more lift.

Both of your airfoils will have a chord of 6" and a span of 5-1/4".

Finally, you will summarize the results of your airfoil test and present your findings to the class.

MATERIALS (per group)

- Airfoil Mount (assume each group builds one airfoil mount to test both airfoils)
  - Foam board pieces (recommend using standard white foam board from Dollar Tree)
    - One (1) 6" x 6"
    - Eight (8) 1" x 3"
  - Wire (can be from a wire hanger)
    - Three (3) 7-1/2" pieces of wire

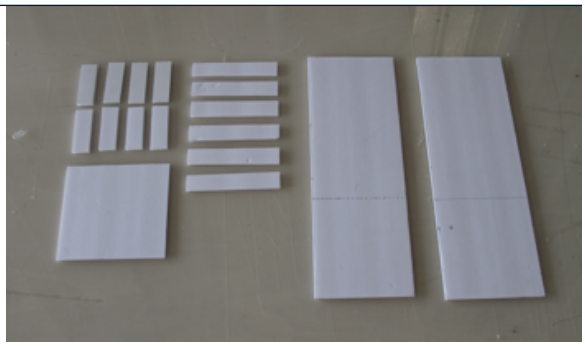
- Symmetrical Airfoil
  - Foam board pieces
    - One (1) 16" x 5-1/4"
    - Three (3) 5-1/4" x 1"
- Asymmetrical Airfoil
  - Foam board pieces
    - One (1) 16" x 5-1/4"
    - Three (3) 5-1/4" x 1"
- Airfoil of Student's Own Design
  - Foam board pieces
    - One (1) 16" x 5-1/4"
    - Three (3) 5-1/4" x 1"
- Box knife
- Metal straight edge
- Measuring tape/ruler
- Hot glue gun and glue sticks
- Pliers/wire cutter
- Protractor
- Safety glasses

SAFETY

- Use eye protection.
- Have insulated gloves available for handling hot objects, and pads for setting down objects with heated surfaces.
- Do not hold sharp objects or tools when they are not in use.
- Sharp tools should be stored in their protective cases as soon as you finish using them.

1 Gather all materials.

2 Measure and cut the foam board pieces needed for the airfoil mount and both airfoils.



3

AIRFOIL MOUNT
Build the two side structures for the airfoil mount.

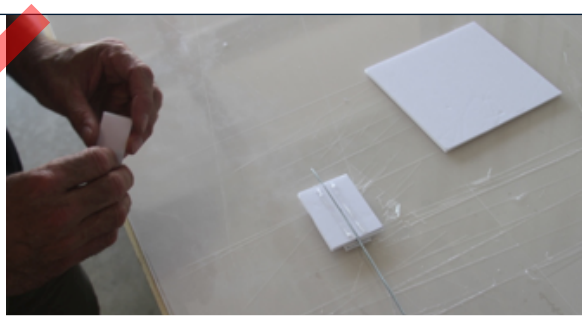
Put one of the pieces of wire between two of the 1" x 3" pieces of foam. You are not gluing the wire to the pieces; it is just providing a spacer. You will pull the wire out once the side structure is assembled.

Apply hot glue to the inside of both foam pieces and center another 1" x 3" piece of foam on top. Press down and let the glue cool.

4

AIRFOIL MOUNT
Build the side structures for the airfoil mount.

Flip the side structure over and repeat the process on the other side. Ensure the hot glue is allowed to cool.



5

AIRFOIL MOUNT
Build the side structures for the airfoil mount.

Once all four pieces are glued together, pull the wire out.

6

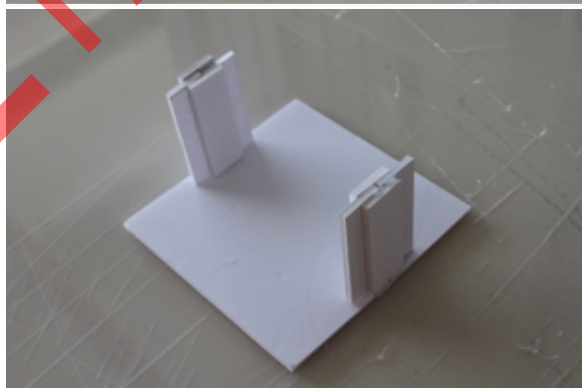
AIRFOIL MOUNT
Build the side structures for the airfoil mount.

Repeat steps 3 through 5 to build a second side structure.

7

AIRFOIL MOUNT
Mount the side structures to the base.

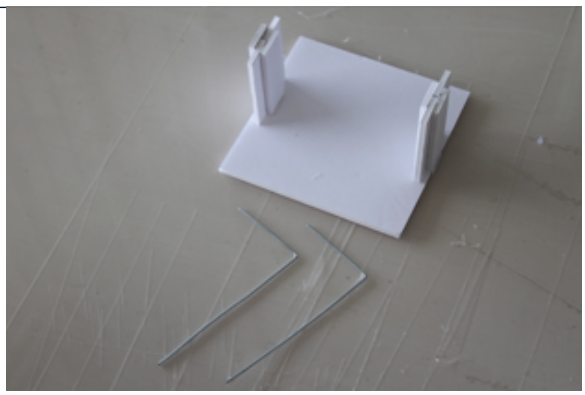
Find the midpoint of one side of the 6” x 6” foam base and glue one of the side structures to the base vertically. Repeat this process on the opposite side of the base.



8

AIRFOIL MOUNT
Prepare the support wires.

Use the pliers to bend two of the 7-1/2” wires at a 90 degree angle. The angle should be made 2-1/2” from one end, leaving 5” remaining for the longer side of the “L” shaped result.



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SYMMETRICAL AIRFOIL

Locate one of the 16” x 5-1/4” pieces of foam board. From one end of the board, draw three lines at the following measurements:

- 5-5/8”
- 6”
- 6-3/8”

10

SYMMETRICAL AIRFOIL

Use the metal straight edge and the box knife to SCORE the three lines. Scoring a line means that you just cut a very shallow line in the paper which guides the fold. DO NOT cut all the way through the foam board. Use minimal pressure to cut a very shallow line.

Score all three lines that you just drew.

11

SYMMETRICAL AIRFOIL

Very carefully and slowly, peel off the top layer of paper from the foam board. DO NOT peel the paper between the lines you just scored. Only peel the paper from the top and bottom portions of the board.

12

SYMMETRICAL AIRFOIL

Use the metal straight edge to help you bend the airfoil around the lines you scored. Complete this task gently and remember the design of a symmetrical airfoil is that both the upper and lower surfaces are identical.

13

SYMMETRICAL AIRFOIL

Continue to work and fold the airfoil evenly using your hands.

14

SYMMETRICAL AIRFOIL

Glue the three pieces of 5-1/4" x 1" foam board to the LONG piece of your board. Glue the pieces 1" below the scored line.

15

SYMMETRICAL AIRFOIL

Once all three 5-1/4" x 1" pieces of foam board are stacked and glued together, apply glue to the top piece and fold the end over. Hold pressure until the glue has cooled.

16

SYMMETRICAL AIRFOIL

Apply glue just under the trailing edge of your airfoil and apply pressure until the glue has cooled.

17

SYMMETRICAL AIRFOIL

Using the straight edge, cut to remove the excess material behind the trailing edge.

18

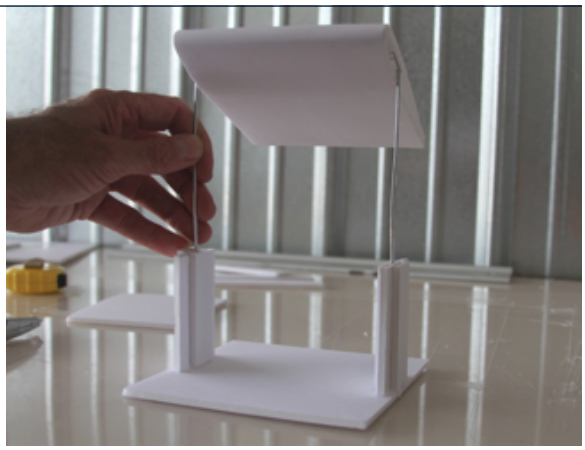
SYMMETRICAL AIRFOIL

Insert the support wires into each end of the airfoil as shown. Insert the end of the wire that is 2-1/2" long into the center of the middle piece of 5-1/4" x 1" foam.

19

SYMMETRICAL AIRFOIL

Insert both wires down the middle of the side support structures of your airfoil mount.

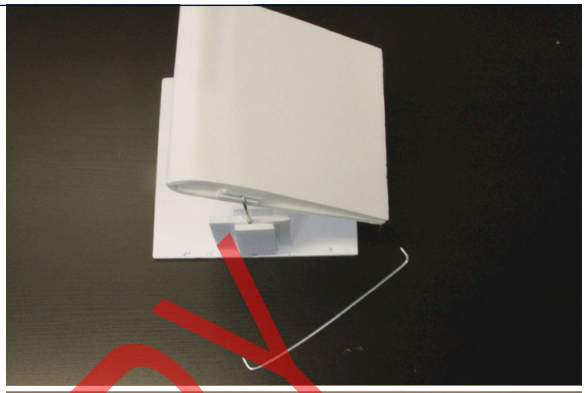


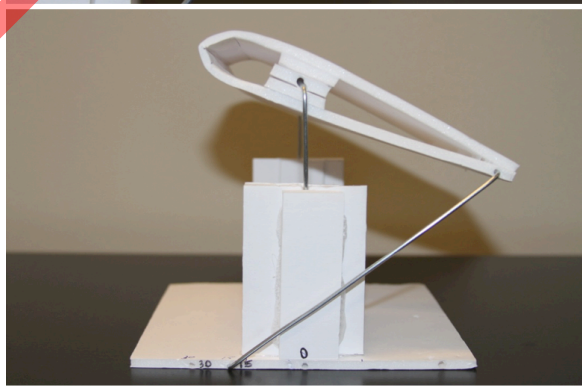
20

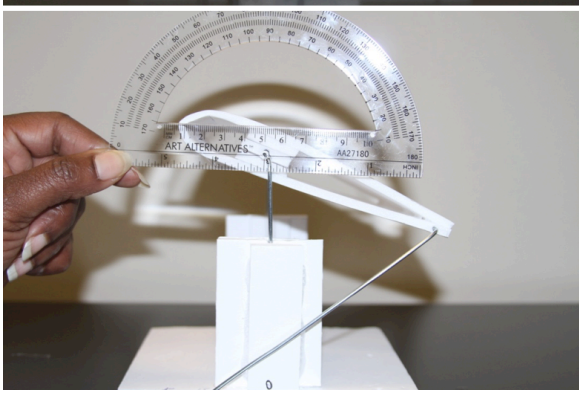
SYMMETRICAL AIRFOIL

Bend the third 7-1/2" piece of wire at both ends. Insert one end of the wire into the trailing edge of your airfoil.

Using the protractor, measure 0, 15, and 30 degrees angle of attack. Insert the wire into the base of the airfoil mount that corresponds with the 3 different angles of attack.







21

ASYMMETRICAL AIRFOIL

Using the second 16” x 5-1/4” board, draw one line 6” from one end of the board.

Score that line and peel off the paper on just the smaller end of the airfoil piece as shown. Once again, be sure to not score the line too deeply.

22

ASYMMETRICAL AIRFOIL

Using the metal straight edge, bend JUST THE SMALLER END OF THE airfoil up. Bend it all the way over the straight edge.

23

ASYMMETRICAL AIRFOIL

Continue to work the fold with your hands.

24

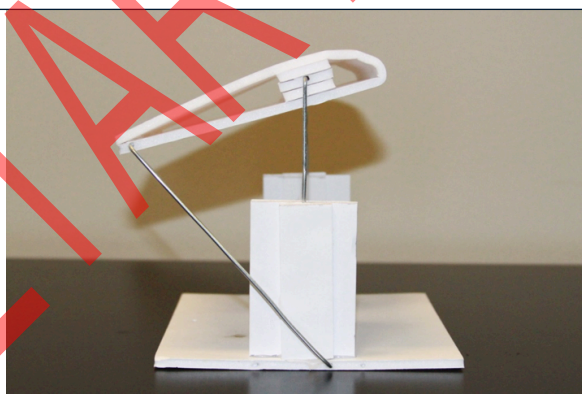
ASYMMETRICAL AIRFOIL

As in step 14, glue the three 5-1/4" x 1" pieces of foam board to the longer section, 1" from your scored line.

25

ASYMMETRICAL AIRFOIL

As in step 20, set the airfoil to 0, 15, and 30 degrees angle of attack.



TEST YOUR AIRFOILS

8. Before you test the airfoils, hypothesize which airfoil will create more lift. How will angle of attack influence the lift created? Explain your reasoning.

Generally, an asymmetric airfoil will generate more lift than a symmetric airfoil at a given angle of attack. Approaching the critical angle of attack, this relationship will vary depending on airfoil shape. Increasing angle of attack increases lift until reaching the critical angle of attack.

To measure the lift of the airfoils, you will note the weight the airfoil assembly exerts on a digital scale before the wind tunnel is on and while the wind tunnel is on.

Take the following steps to measure lift:

1. Place the digital scale inside the wind tunnel.
2. Ensure the digital scale has been "zeroed" out.
3. Place the airfoil mount and the symmetrical airfoil on the scale.
4. Looking through the viewing window, take note of the weight in grams (to the tenth or hundredth) before the wind tunnel is turned on.
5. Turn on the wind tunnel (ensure the fan is at the highest power setting).
6. After a few moments, take note of the new weight in grams (to the tenth or hundredth).
7. Subtract the weight found in step 6 from the weight found in step 4 to determine the amount of lift generated.
8. Repeat these steps for both airfoils and the different angle of attacks.

Student answers will vary.

	ANGLE OF ATTACK	WEIGHT IN GRAMS BEFORE	WEIGHT IN GRAMS DURING THE TEST	LIFT GENERATED (G)
SYMMETRICAL AIRFOIL	0 degrees			
	15 degrees			
	30 degrees			
ASYMMETRICAL AIRFOIL	0 degrees			
	15 degrees			
	30 degrees			

9. Which airfoil produced the most lift? Explain why.

Student answers will vary. The correct answer is that the asymmetrical airfoil should produce the most lift. The asymmetrical airfoil's curve is closer to the leading edge, which produces more lift.

10. Which airfoil produced the most lift for a given angle of attack? Why?

0 degrees - The asymmetrical airfoil should produce more lift.

15 degrees - The asymmetrical airfoil should produce more lift.

30 degrees - This may vary based on students' results.

11. Go back to your wind tunnel with your asymmetrical airfoil. Mount the airfoil upside down so that the cambered side of the airfoil is facing the scale. Place the entire airfoil mount on the scale with the leading edge pointed towards the fan. Note the weight again before turning on the fan. What happens to the weight once the wind tunnel is turned on? Why?

The weight increases when the wind tunnel is turned on. The upside down asymmetrical airfoil generates negative lift and makes the airfoil heavier.

12. What would you expect if we did the same exercise with the symmetrical airfoil?

The symmetrical airfoil, if turned upside down, would generate the same lift if right side up. It doesn't matter, so that is why this airfoil is better for aerobatic airplanes who go upside down as they perform.

Share your findings

13. An important aspect of engineering design is presenting your findings. Put together your results to share with the rest of the class. Be prepared to describe what limitations you encountered, errors you made, and ideas you have for improving the design of your airfoils and improving the testing methods.

Students can use this space to write notes related to the tests they conducted.