2004 Transportation Education Academy Activity:

How An Airplane Wing Creates Lift

Standards being met for technological literacy:

1. Number 8
2. Number 9
3. Number 11
4. Number 18

Description:

In this activity, students will learn the basic principles of flight and lift of an airplane wing. Why the shape determines how much lift the wing will produce, and design, build and test a wing.

Objectives:

At the end of this activity the students should be able to:

1. Have a basic understanding of *Bernoulli's principle*.
2. Know what the *law of continuity* is.
3. Have a basic understanding of *Newton's laws of force and motion.*
4. Know one of the *four forces of flight* (lift).

Group size:

This activity would work well with individuals or groups of two.

Time:

This activity should take a couple of hours depending on class size.

Background information:

Newton's laws of force and motion are:

1. A body at rest tends to stay at rest, and a body in motion tends to stay in motion at the same speed and direction. For example, a plane sitting on the ground will stay there until a force is applied to move it.

2. When a body is acted upon by a constant force, its acceleration is inversely proportional to the mass of the body and is directly proportional to the applied force. F=ma or Force = mass x acceleration.

3. for every action there is an equal and opposite reaction.

Daniel Bernoulli was a Swiss mathematician who devised the equation $p+\frac{1}{2}\rho V^2$ = constant. Or more simply put, *static pressure* + *dynamic pressure* = *constant.* What this means is a mass of stationary air in a container exerts a certain amount of pressure (4 + *dynamic pressure* = *constant*).

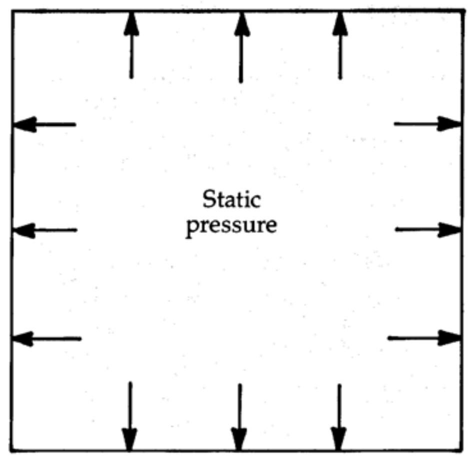


Fig. 1

In this case 4+0 = 4 (See Fig. 1). If the air was moving through the container and the container had a wall in it, the pressure on the wall is the dynamic pressure.

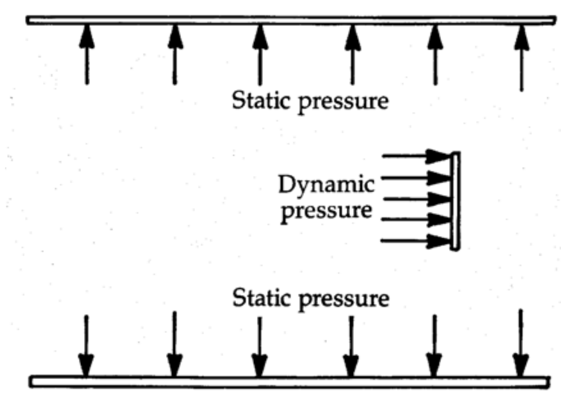


Fig.2

Now if the constant is still 4 and the dynamic pressure is 2, then the static pressure must now be 2. (*static* 2+*dynamic* 2=*constant* 4, See Fig. 2).

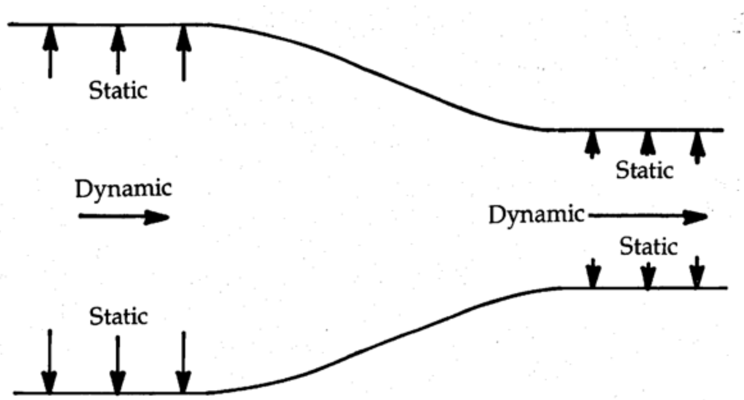


Fig.3

The laws of continuity state the area times the velocity equals a constant. A x V = constant. In Fig. 3 if the static (area) on the left is 2 and the dynamic (velocity) on the left is 1, then the constant would be 2. As the air moves to the right and the static (area) becomes 1 and the dynamic (velocity) becomes 2 the constant is still 2.

Bernoulli's principle is based on Newton's second law of motion that says there is a requirement of an unbalanced force (pressure) to produce acceleration. When looking at the left side of Fig. 3, as the air moves to the right the dynamic pressure is increasing while the static pressure is decreasing. This creates a vacuum so if you were to hook a hose to the skinny part of Fig. 3 there would be suction. For example if the dynamic air entering to the right is a 2 and the static air is a 2 then the constant is 4. *static (2) + dynamic (2) = constant (4).* As the air travels to the right the static pressure decreases to 1 and the dynamic pressure increases to 3 the constant is still 4. *static (1) + dynamic (3) = constant (4).*

Take out a piece of paper about two inches by eight inches. Hold one end of it between your thumb and index finger. With your thumb facing you and the paper lying across the tops of your fingers, blow across the top of your thumb. The paper should rise and you should see a simple example of static and dynamic pressure.

Now if you imagine that the bottom of Fig. 3 is the top of an airplane wing you can see that at the top of the wing there is low pressure, and according to Newton's laws there must be an equal and opposite reaction, therefore there is high pressure on the bottom side creating lift. (Fig. 4)

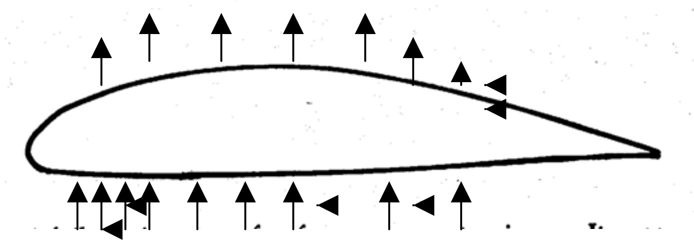


Fig.4

Figures 5 and 6 are examples of some airplane wings.

Fig. 5

Fig. 6

<u>Supplies tools and materials:</u>

To complete this activity you will need the following materials:

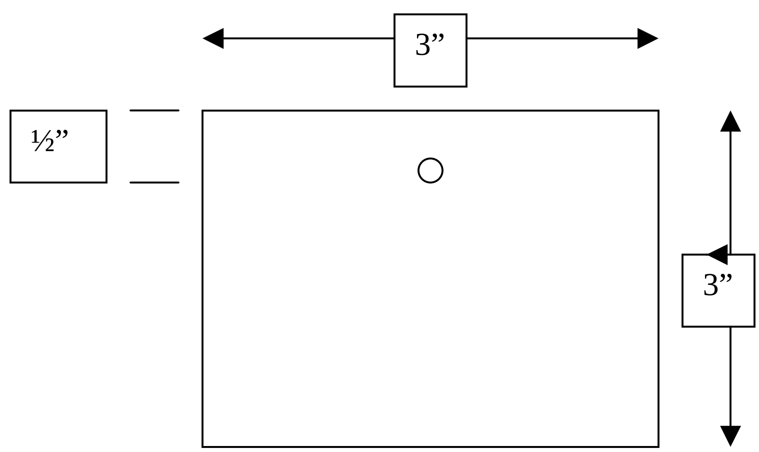
1. Balsa wood for wing material.
2. Pencil for drawing the wing on the balsa.
3. Band saw or sanding wheel for cutting and shaping the wing.
5. Sandpaper for shaping the wing.
6. Machine bolts and nuts to hold the wing in place and hold the washers.
7. Washers for weights.
8. Drill and drill bit.
9. Wind generator (fan, hair dryer).
10. A stand will need to be built by the instructor previous to the wing testing to hold the wings in place. (See instructions for building the stand)

Safety Precautions:

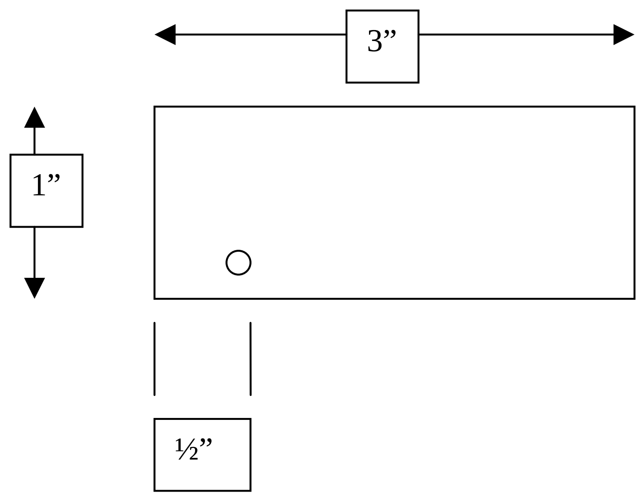
1. Always follow the safety rules of the school and classroom.
2. Always wear safety glasses when cutting, sanding and drilling the wood.
3. Provide ear protection when using loud machinery and tools.

Procedure:

1. Hand out the wood according to groups or individuals.
2. Have students drill one hole through the wood ½" from the leading edge of the wing from top to bottom. (See Fig. 7)
3. Students should drill a hole into each side of the wood ½" from the leading edge about a ½" deep. (See Fig. 8)



Top view
Fig. 7



Side view
Fig. 8

3. Draw the shape of the wing they wish to test on the side of the balsa wood being careful not to get to close to the holes so they don’t interfere.
4. Cut out the shape or sand down with sanding wheel.
5. Use sandpaper to finish the wing.
6. Put the machine bolt through the wing from the top. Once it’s through screw a nut on the bolt. This will hold the washers (weights) and keep the wing from tilting up and down which would change the angle of attack.
7. Mount the wing in the stand.
8. Turn on the wind source and record maximum number of washers it will lift.
9. Winner gets bragging rights.

Building the stand:

The stand only needs to be tall enough to hold the wing and the washers above the surface. It can be made out of any material but I think clear lexan is best. The stand is built from only three pieces, a base and two sides. The sides need to have a slot cut into them about 1 inch long and wide enough for the screws that mount into the side of the wing to move up and down freely within the slot. See Fig. 9

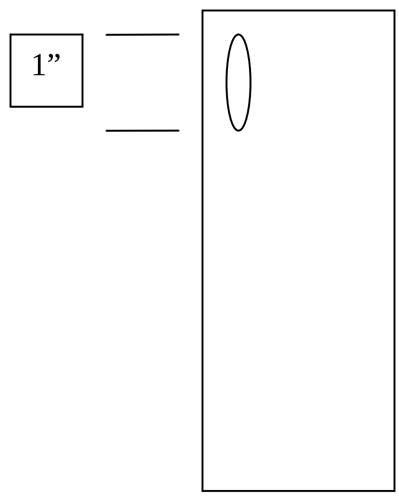


Fig. 9

Evaluation and assessment:
Test questions:

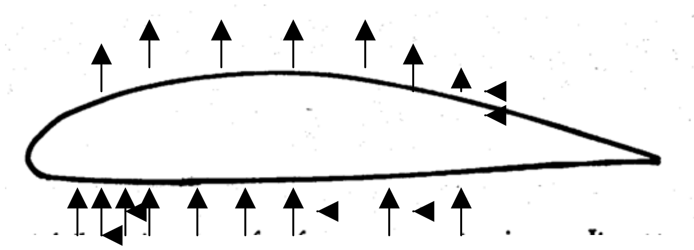
1. In Bernoulli's principle the simplified equation is static pressure + _______= constant.

2. The formula for the law of continuity is
    a. area + velocity = constant.
    b. area x velocity = constant.
    c. area / velocity = constant.
    d. area - velocity = constant.

3. What type of pressure does stationary air exert?

4. What type of pressure was hitting the sides of Fig. 3?

5. In the picture, name the high pressure side and the low pressure side.



6. What creates the high pressure area on the wing?

7. If the shape of the wing above were to be more curved on the bottom, how would that effect the lift and why?

8. Do you think one principle is more important in the creation of lift on an airplane wing then another and why or why not?

9. How much of this activity did you already know?

10. If you didn't know the principles or laws have you heard of them before?