



# THE DYNAMICS OF FLIGHT

## Pre-Test

Name \_\_\_\_\_

**Fill in the Blank Directions:** Fill in the blank with a word from the list on the right. Not all the words will be used.

1. There are four forces active on an airplane. Those forces are \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_.
2. The \_\_\_\_\_ of an airplane is used to turn the nose of the plane.
3. Flaps on the wings used to raise and lower the wings are called \_\_\_\_\_.
4. If the control wheel is pushed forward, or pulled back, it is changing the position of the \_\_\_\_\_.
5. The engine of the plane is controlled by the \_\_\_\_\_.

### Word list

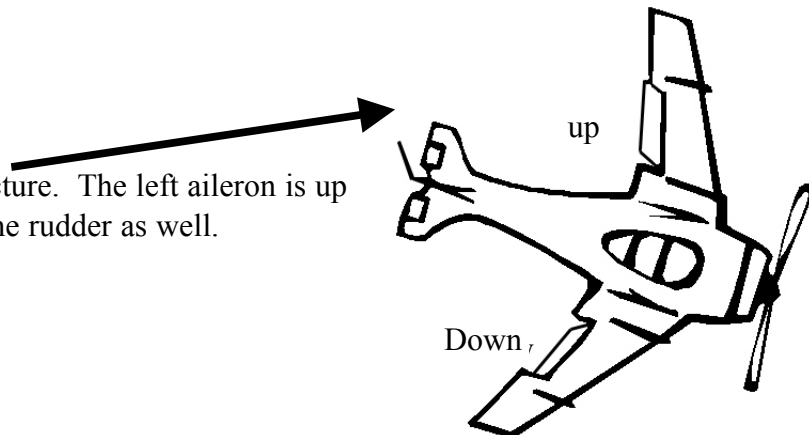
thrust	lift
throttle	gravity
pitch	Newton
density	pressure
drag	elevators
ailerons	rudder
yaw	roll
Bernoulli	fuselage

**Short Answer Directions:** Use complete sentences to answer the following questions.

1. What is Bernoulli's Principle?
2. What is Newton's Third Law of Motion?
3. How does a soda straw work? Describe in scientific fashion what is happening when we use a soda straw to drink from a glass or cup.
4. Here is a picture of a cross section of an airplane's wing. Why is it shaped like this?



5. Describe what is happening in this picture. The left aileron is up and the right aileron is down. Look at the rudder as well.





# THE DYNAMICS OF FLIGHT

## Program Quiz

Name \_\_\_\_\_

**Multiple Choice Directions:** Choose the best answer for each question.

1. The force that opposes the forward motion of an airplane is called \_\_\_\_\_.  
 a. thrust                      b. lift                      c. drag                      d. gravity
2. The engine of an airplane provides \_\_\_\_\_.  
 a. thrust                      b. lift                      c. drag                      d. gravity
3. The wings of an airplane are designed to provide \_\_\_\_\_.  
 a. thrust                      b. lift                      c. drag                      d. gravity
4. The \_\_\_\_\_ are used to raise or lower the wings.  
 a. ailerons                      b. elevators                      c. rudder                      d. pitch
5. The \_\_\_\_\_ are used to raise or lower the tail of a plane and cause the nose to rise or dip.  
 a. ailerons                      b. elevators                      c. rudder                      d. pitch
6. The direction of the plane from left and right is controlled by the \_\_\_\_\_.  
 a. ailerons                      b. elevators                      c. rudder                      d. pitch
7. The engine speed is increased or decreased with the use of the \_\_\_\_\_.  
 a. ailerons                      b. elevators                      c. throttle                      d. yaw
8. The pilot controls the \_\_\_\_\_ with foot pedals.  
 a. ailerons                      b. elevators                      c. rudder                      d. throttle
9. Air pressure at sea level is 14.7 pounds per square feet, or \_\_\_\_\_.  
 a. 1 kilogram per square centimeter                      b. 1.5 kilograms per square centimeter  
 c. 2 kilograms per square centimeter                      d. 2.5 kilograms per square centimeter
10. The idea that pressure in a fluid decreases when its speed increases was established by \_\_\_\_\_.  
 a. Leonardo da Vinci                      b. Wilbur Wright                      c. Daniel Bernoulli                      d. Orville Wright



# THE DYNAMICS OF FLIGHT

## Vocabulary

Name \_\_\_\_\_

**Directions:** Match the definition in column B with the word in column A.

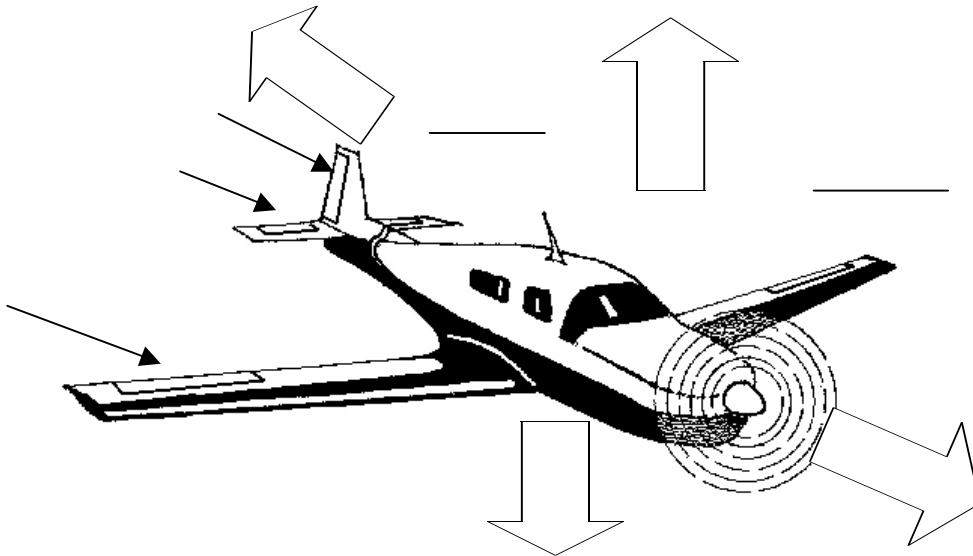
### Column A

1. thrust \_\_\_\_\_
2. drag \_\_\_\_\_
3. gravity \_\_\_\_\_
4. lift \_\_\_\_\_
5. angle of attack \_\_\_\_\_
6. aileron \_\_\_\_\_
7. rudder \_\_\_\_\_
8. elevators \_\_\_\_\_
9. throttle \_\_\_\_\_
10. pitch \_\_\_\_\_
11. yaw \_\_\_\_\_
12. roll \_\_\_\_\_
13. Bernoulli's Principle \_\_\_\_\_
14. Newton's Third Law \_\_\_\_\_
15. fuselage \_\_\_\_\_

### Column B

- A. Used to control the speed of the plane's engine.
- B. Ailerons are raised on one wing and lowered on the other.
- C. The force that gives the plane weight and pulls it towards the ground.
- D. For every action there is an opposite and equal reaction.
- E. The forward motion of a plane.
- F. The upward force created by the wings of a plane.
- G. Used to turn the tail of the plane and point the nose in a new direction.
- H. The position of the wings with respect to how the air strikes them.
- I. A force that opposes the forward motion of a plane.
- J. A name for the body of a plane.
- K. Faster moving fluids have less pressure than slower moving fluids.
- L. Makes the nose of the plane go up or down and the plane to climb or descend.
- M. The turning of a plane.
- N. Parts of the wing that can move up or down to tilt the wing.
- O. Found on tail of plane to change the upward or downward position of the nose.

**Directions:** Label the picture of an airplane with these terms: ailerons (2), elevators (2), rudder, thrust, drag, lift, and gravity.





# THE DYNAMICS OF FLIGHT

## Bernoulli's Principle

Name \_\_\_\_\_

Daniel Bernoulli, a Swiss scientist, studied the speed and pressure of fluids in the 1700s. He noticed that the speed of water flowing in a stream would increase as the water flowed in narrow parts. The speed of the fluid increased, but the pressure of the fluid decreased. He stated his principle as the pressure in a fluid decreases as the speed of the fluid increases.

Air is a fluid. We don't think of air as a fluid, such as water, but it is. You can perform some simple experiments that illustrate Bernoulli's Principle in action.

### TWO SHEETS OF PAPER

Hold two sheets of paper, one in each hand, about two inches apart. What do you think will happen if you blow down between the sheets of paper. Circle your choice before performing the experiment.

- The papers will fly apart.
- The papers will come together.
- The papers will not move.

Try the experiment. What happened? \_\_\_\_\_

What is your explanation? Why does this happen? \_\_\_\_\_

\_\_\_\_\_

### PAPER UNDER YOUR CHIN

Hold one end of a piece of paper below your mouth and against your chin. What do you think will happen if you blow across the paper with a steady stream of air? Circle your choice before trying the experiment.

- The paper will rise as if pushed from underneath.
- The paper will go down.
- The paper will do nothing but stay in its curved position.

Try the experiment. What happened? \_\_\_\_\_

What is your explanation? Why does this happen? \_\_\_\_\_

\_\_\_\_\_

### INDEX CARD

Take an index card and bend each end down to form two legs. The legs should be about an inch (10 cm) long. Set the card so that it is standing on these legs on a table. Now blow under the card to try and blow it over. What do you think will happen? Circle your choice before trying the experiment.

- The card will fly into the air easily. It's only thin card stock.
- The card will fly across the table.
- The card center will flatten to the table as if pushed from above.

Try the experiment. What happened? \_\_\_\_\_

What is your explanation? Why does this happen? \_\_\_\_\_

\_\_\_\_\_



# THE DYNAMICS OF FLIGHT

## Bernoulli's Principle Demonstrated

### SPOOL AND CARD

**Purpose:** To demonstrate Bernoulli's Principle as it applies to air as a fluid

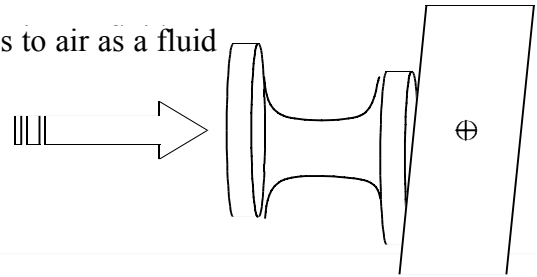
**Materials:** index card  
pin  
spool of thread

**Procedures:**

1. Push a pin through the center of an index card.
2. Place the pin inside the hole of a spool of thread.
3. Blow through the other end of the spool and try and cause the index card to fly away from the spool.
4. Try this in all directions.

**Observations:** What happened? \_\_\_\_\_

**Conclusions:** How do you explain this? \_\_\_\_\_



### VACUUM CLEANER

**Purpose:** To demonstrate Bernoulli's Principle as it applies to air as a fluid.

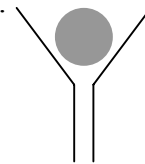
**Materials:** vacuum cleaner with the option to blow air  
funnel (glass if possible)  
pingpong ball

**Procedures:**

1. Set the vacuum cleaner so that it blows air rather than suck it in (Some vacuum cleaners have this option).
2. Place the funnel in the vacuum cleaner nozzle with the neck of the funnel inside the vacuum hose.
3. Turn the funnel and vacuum hose up and drop the pingpong ball into the funnel.
4. Turn on the vacuum so that it is blowing out air.
5. Turn the funnel and hose upside down so that the mouth of the funnel is facing the ground.

**Observations:** What happened? \_\_\_\_\_

**Conclusions:** How do you explain this? \_\_\_\_\_



### Follow-up demonstration:

Use the vacuum cleaner in its blowing mode to suspend a pingpong ball in a stream of air. Take the funnel out of the vacuum hose nozzle and face the hose upward. Turn the vacuum on and carefully place the pingpong ball in the air stream. The ball will go up to a certain height and then, if you are careful, will stay suspended in the air stream. You can even rotate your body slowly from side to side and cause the ball to move as well.

How do you explain the behavior of the pingpong ball in the stream of air?



# THE DYNAMICS OF FLIGHT

## Air Pressure-Page One

Name \_\_\_\_\_

You may have watched a giant commercial airplane carrying hundreds of people and all their luggage speed down an airport runway and lift off the ground and into the air. Did you ever wonder how it is possible that such a huge and heavy aircraft could do this with such grace and ease? Well, air pressure supplies part of this lifting ability. Bernoulli had figured out hundreds of years ago that the pressure of a fluid decreases as the speed of the fluid increases. With that in mind, the wings of airplanes are shaped to cause the air rushing over the top of the wing to travel a greater distance than the air under the wing. The wing is curved as shown in the illustration. The air above the wing must travel faster to cover a greater distance and still reach the back of the wing at the same time as the air moving below the wing. Because the air travels faster above, it has less pressure than the air below the wing. The greater air pressure below the wing helps to lift the wings and the plane into the air. The faster the plane is moving forward, the faster the air moves over the wing. A glider doesn't have to move really fast because it has very long wings, and therefore, a lot of lift from air pressure. An air force jet has small wings but can travel forward very fast because of powerful jet engines.

Try these experiments that demonstrate the strength of air pressure.

### WATER IN A SODA STRAW

Take a soda straw and plunge one end into a glass of water. Now bring the straw out and notice that no water comes out inside the straw. Repeat but this time before removing the straw from the glass put your thumb over the end of the straw. This time water is lifted out of the glass inside the straw.

What is your explanation? Why does this happen? \_\_\_\_\_

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What happens when you lift your thumb from the end of the soda straw?

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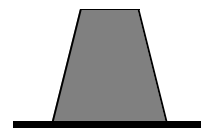
### GLASS OF WATER DEFIES GRAVITY

Fill a glass with water to the very brim. Slide an index card across the mouth of the glass so that it covers the entire glass mouth. Now with one hand hold the index card in place and carefully turn the glass upside down. Let go of the index card.

Try the experiment. What happened? \_\_\_\_\_

What is your explanation? Why does this happen? \_\_\_\_\_

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# THE DYNAMICS OF FLIGHT

## Air Pressure-Page Two

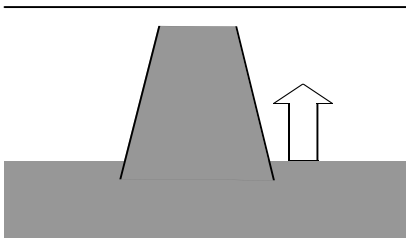
Name \_\_\_\_\_

Here are some more simple experiments to demonstrate the strength of air pressure.

### GLASS OF WATER LIFTED UP WITH ITS MOUTH BELOW THE WATER SURFACE

In a sink or bucket of water submerge a drinking glass. Turn the glass sideways to allow the air to escape and water to fill the glass. Now turn the glass so the mouth is facing down and lift it straight up. Lift the glass above the water line but stop before the mouth of the glass goes above the waterline.

Why does the water remain in the glass? \_\_\_\_\_



### CAN WITH HOLE PUNCHED IN IT

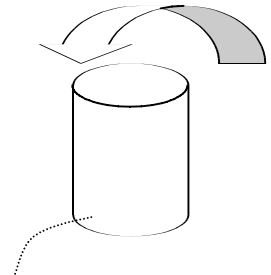
Use a nail and hammer to punch a hole near the bottom of the can. Fill the can with water and then firmly place your hand over the opening of the can. If you completely cover the opening of the can with the palm of your hand the water will stop squirting out the hole.

Why does the water stop coming out the hole of the can?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_



### CORK IN A GLASS OF AIR

Fill a sink or bucket with water. Float a cork on the surface of this water. Turn an empty glass upside down and bring it over the cork so that the mouth of the glass is on the surface of the water. Now push the glass down.

What happens? \_\_\_\_\_

How do you explain this? \_\_\_\_\_



# THE DYNAMICS OF FLIGHT

## Soda Straw

Name \_\_\_\_\_

Everybody has used a straw to bring the refreshing liquid of a milk shake or soda drink into our thirsty mouths. But have you ever thought about how a soda straw works? Well, it is air pressure that brings that fluid into your mouth. You suck on the straw and remove some of the air from the inside of the straw. Now the air pressure inside the straw is less than the air pressure around it. The air pressure above the glass pushes the fluid in the glass into the straw as the air pressure tries to get into the straw and even the pressure out again. You can prove this with a simple experiment.

1. Get a soda or milk shake with a lid or cap for the drink container. First, use the straw to drink some of the fluid without the lid on the container.
2. Next, place the cover on the container and poke the straw through the hole provided in the lid. Now, again, draw the fluid through the straw as normal. It should work smoothly.
3. Now, with the straw still in the lid hole, use tape to close up any gaps between the straw and hole. Look carefully at the lid to see if any other parts of the lid need to be closed with tape.
4. Once again, try bringing fluid through the straw.

What happens this time?

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What does this demonstrate?

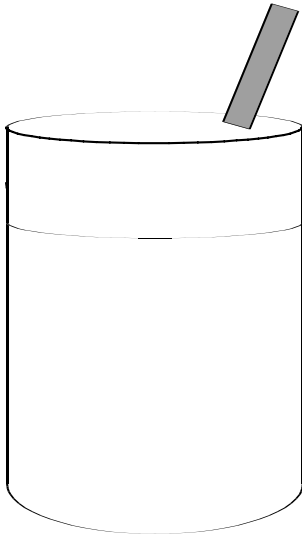
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# THE DYNAMICS OF FLIGHT

## Strength of Air Pressure

Name \_\_\_\_\_

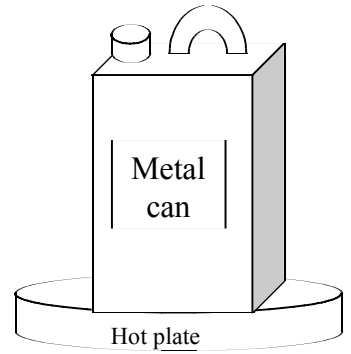
This experiment requires the use of heat, so it may work best as a demonstration.

**Purpose:** To demonstrate the strength of air pressure.

**Materials:** Five-liter or five-gallon metal can with a screw cap and, if possible, a handle  
 Hot plate  
 Measuring cup  
 Water  
 Oven mitt or tongs for lifting the can

**Procedures:**

1. Pour about one-half cup of water into the metal can.
2. Place the can on a hot plate and turn the hot plate on to heat the water inside the can.
3. When steam is coming out of the can at a steady pace, put on the oven mitt and screw the cap onto the can.
4. Using the oven mitt or tongs lift the can from the hot plate.
5. Set the can down and observe what happens as the steam inside the can cools.  
 (You can speed things up dramatically if you pour some cold water over the outside of the can).



**Observations:**

What happens to the capped can as the steam inside is cooled and changed back into water?

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**Conclusions:** How do you explain what happened in this demonstration?

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# THE DYNAMICS OF FLIGHT

## Shape of the Wings

Name \_\_\_\_\_

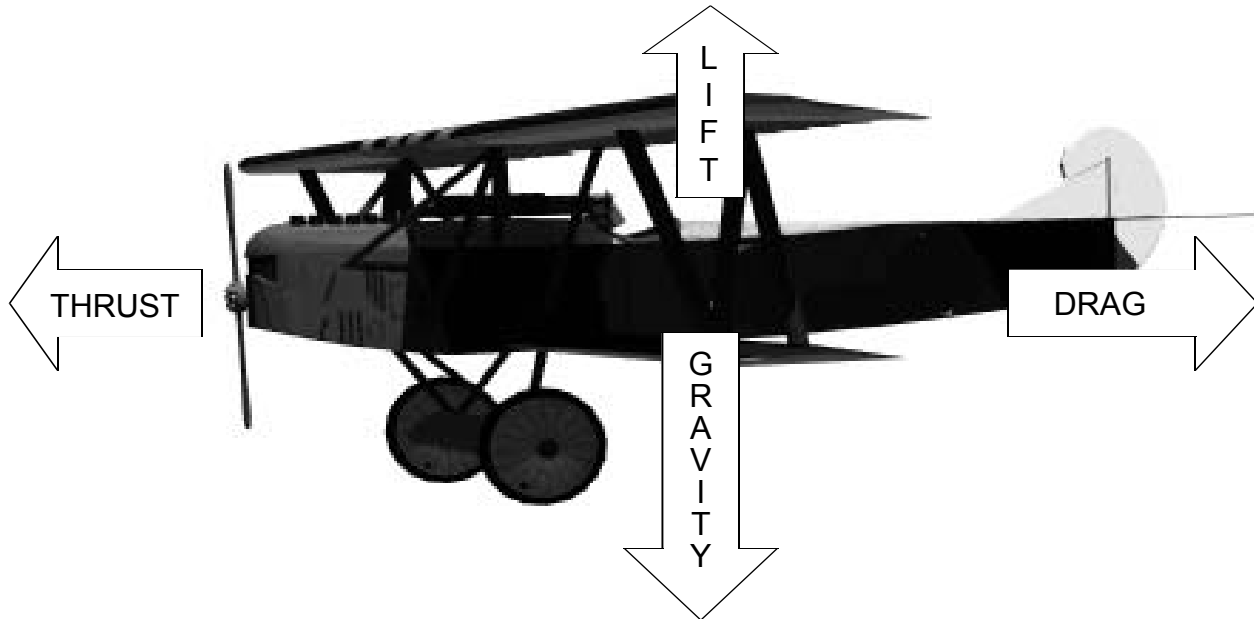
There are four forces active on a plane as it is flying. Here, those four forces are defined.

**Gravity** - The force that pulls the plane towards the ground. It is represented as the weight of the plane and everything it is carrying.

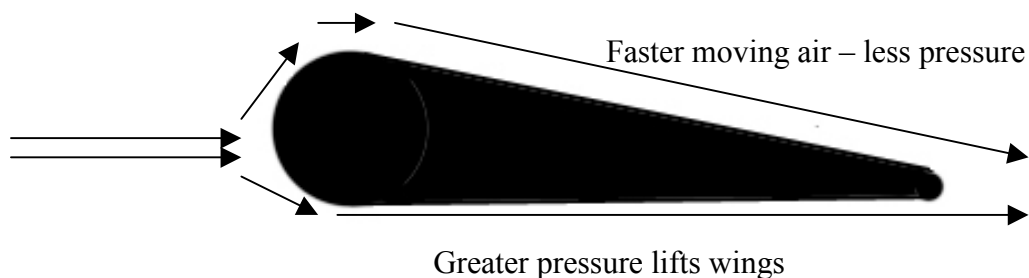
**Lift** - The force that opposes gravity allowing the plane to rise into the air.

**Thrust** - The forward movement of the plane.

**Drag** - A force created by the contact of the air and the body of the plane. It opposes thrust and slows the forward motion of the plane.



Wings are designed in a special way to create lift. If you look at the wing of a plane from the side, you will see that it is shaped in a curved fashion as illustrated below. The reason for this curve is to take advantage of Bernoulli's Principle, which was first discovered back in the 1700s. Bernoulli discovered that when a fluid moves fast, its pressure decreases. Since air is considered a fluid, this discovery can be applied to the design of a wing. The upper side of the wing is curved, which creates a greater distance for the air to travel over the wing and still meet with the air that is moving below the wing. As a result, the air over the wing must travel faster. Because that air is moving faster, it has less pressure and the greater pressure below the wing lifts the plane up. Lift is also created by the angle of the wing. This is called the angle of attack and has to do with the angle of the wing with respect to the oncoming air. However, if the angle of attack is too great, the air doesn't move smoothly and lift is lost. The amount of lift is determined by the speed, or thrust, of the plane through the air or the surface area of the wing. Gliders, which don't have engines to provide thrust, rely on large wings. Jet fighters have powerful engines and often don't need large wings.



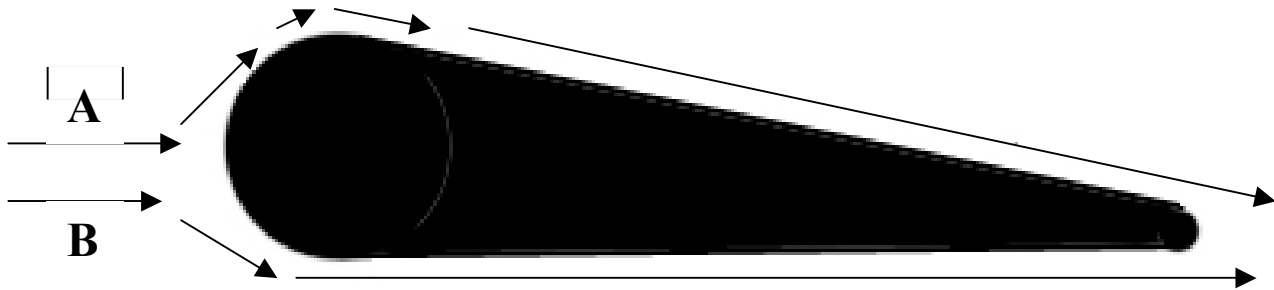


# THE DYNAMICS OF FLIGHT

## Wing Design

Name \_\_\_\_\_

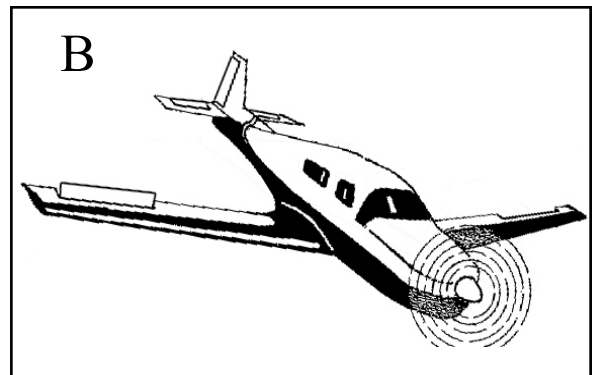
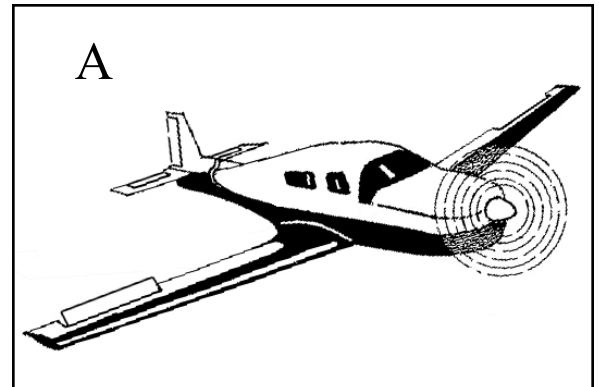
The wings of a plane are curved in such a way that the air moving over the top of the wing has a greater distance to travel than the air moving below the wing. So if we think of the air splitting into two different streams, one we will call A and the other B. Both streams must meet at the end of the wing at the same time. Stream A traveling over the top of the wing has a greater distance to travel, and therefore, must travel faster to arrive at the back of the wing at the same time as stream B. Bernoulli proved that when fluids move faster, their pressure decreases, so the air pressure above the wing will be less than the air pressure below the wing. The greater pressure below the wing lifts the plane into the air.



During flight, ailerons, or flaps, are used to control the plane. During take-off and landing, ailerons, or flaps, on the wings are used to change the amount of lift on the wings. By moving the ailerons up or down, you can change the distance the air must travel, and therefore, change the amount of lift.

Ailerons on the wings are used to tilt the wings up or down. In the two pictures to the right, the left aileron is up and the right aileron is down.

**Which picture shows how the wings would respond to this setup? A or B**



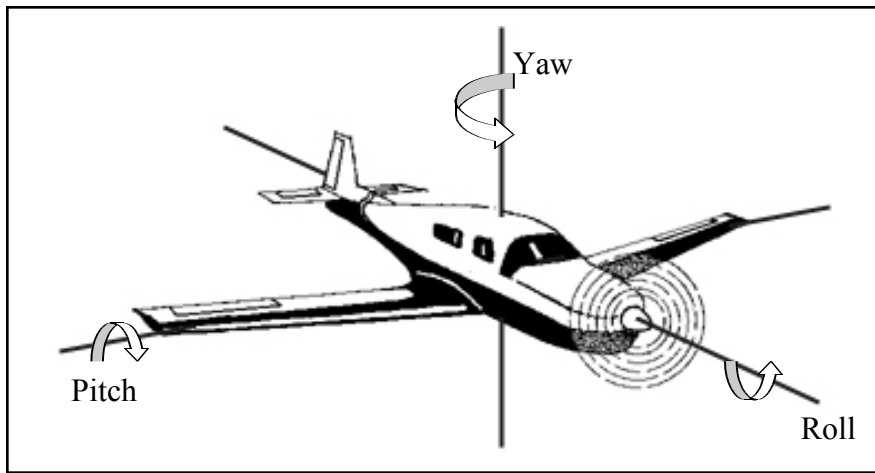


# THE DYNAMICS OF FLIGHT

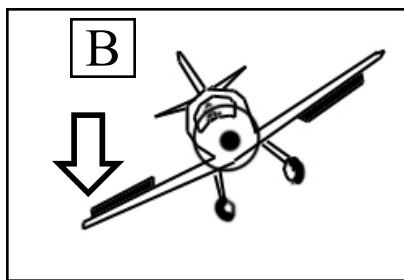
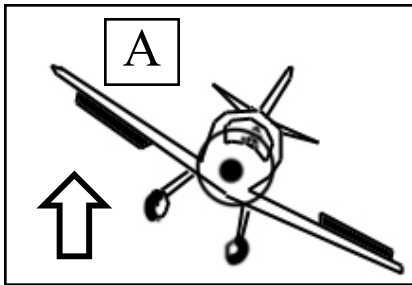
## Control

If you looked inside the cockpit of an airplane, you would see many instruments and controls. Some of the instruments are designed to supply information about the altitude and direction of the plane. One instrument gives the speed of the plane. The throttle is used to control the engine power. The pilot pushes the throttle in to increase the engine power, and pulls the throttle out to decrease the power. The control wheel is turned to the left or right to control the ailerons, which are on the wings and are used to raise and lower the wing. The foot pedals are used to control the rudder, which is used to turn the tail, which changes the direction of the nose of the plane. On the ground, the plane's direction is controlled by the rudder, so a pilot uses his/her feet to control the movement of the plane on the runway. The foot pedals are also used to apply the brakes. The left wheel brake is controlled by the left foot pedal, and the right wheel brake is controlled by the right pedal. On the ground, the plane can turn very quickly because one brake can be applied like treads on a tank.

When a plane is in flight, there are three imaginary axes of rotation. These lines run through the weight center, or center of gravity, of the plane. The airplane's rotation around these axes is called pitch, roll, and yaw.

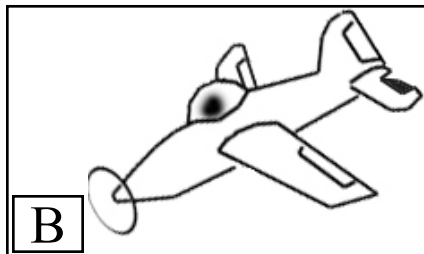
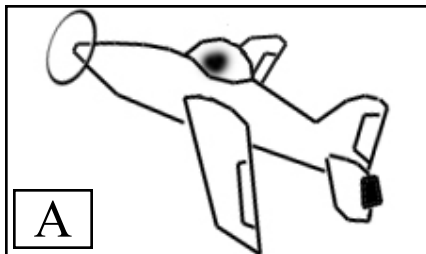


**R  
o  
l  
l**



The ailerons are used to raise and lower the wings. The pilot uses the control wheel to roll the wings. Turning the control wheel right causes the right aileron to raise the right aileron and lower the left aileron. The plane rolls right (picture B).

**P  
i  
t  
c  
h**



The pitch of the plane is controlled by the elevators on the tail of the plane. They are controlled by the control wheel. If the wheel is pulled back, the elevator goes up, causing the nose to go up and the plane climbs (A). If the control wheel is pushed forward, the elevators go down and the nose dips, causing the plane to lose altitude (B).

**Y  
a  
w**



The yaw is controlled by the rudder. The pilot uses the right foot pedal to turn the rudder right, which causes the tail to yaw to the left and the nose to yaw to the right. To smoothly bank a plane, or have it turn left or right, the pilot uses the ailerons and the rudder together.

