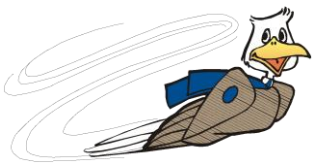


*Civil Air Patrol's ACE Program*

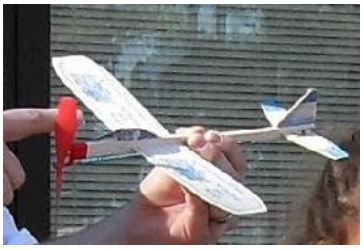
# Forces of Flight
# Grade 5 Academic Lesson #2

**Topics**: forces, motion (science, language arts)

**Length of Lesson**: 45 minutes

**Objectives**:

- Students will identify and define the four forces of flight: weight (or gravity), lift, thrust, and drag.
- Students will demonstrate the four forces of flight.
- Students will experiment with flight.



**Next Generation Science Standards:**

- Support an argument that the gravitational force exerted by Earth on objects is directed down. (5-PS2-1)
- Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved. (3-5-ETS1-3)

**CCSS ELA:**

- SL 5.4 - Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.
- L 5.6 - Acquire and use accurately grade-appropriate general academic and domain-specific words and phrases, including those that signal contrast, addition, and other logical relationships

**Background Information**:

For a very simple, but clear, description of the four forces of flight, you may wish to watch (and/or share with the students) the video, "How Do Airplanes Fly?"

Explaining how and why an airplane flies is very complex; however, the following simple explanations will help students acquire an elementary understanding of the forces of flight.

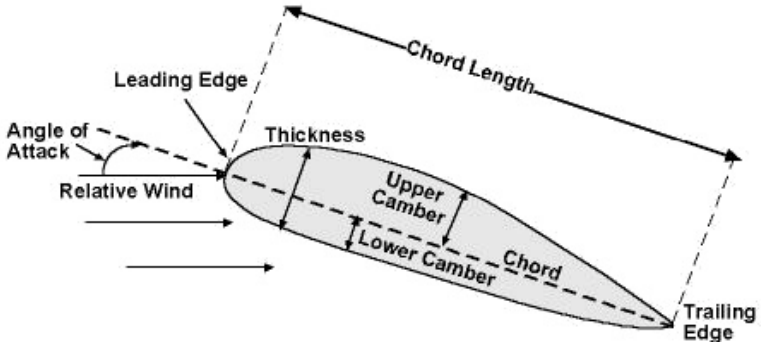
- Thrust is a force that moves an object in the direction of motion. It can be created with a propeller, jet engine, or rocket. With a propeller or jet engine, air is pulled in and then pushed out in an opposite direction. A household fan can demonstrate this. Throwing an object, such as a Frisbee or a paper airplane, also creates thrust. Thrust is the opposite force to drag.

- Drag is the force that acts opposite to the direction of motion. It tends to slow an object. Drag is caused by friction and differences in air pressure. An example of drag is putting your hand out of a moving car window and feeling it pull back. Drag is the opposite force to thrust.

- Weight is the force caused by gravity; the downward force toward the center of the earth. Weight is the opposite force to lift.

- Lift is the force that acts at a right angle to the direction of motion through the air. Lift is created by differences in air pressure. The wings create most of the lift used by airplanes. Lift is created due to angle of attack (the angle that the wings make against the air flowing towards them). Angle of attack relates to Newton's laws of motion. Depending on how the air is "hitting" and moving away from the wing affects the altitude of the plane.

  The angle of attack is the angle at which relative wind meets an airfoil (shape of a wing). It is the angle that is formed by the chord of the airfoil and the direction of the relative wind or between the chord line and the flight path. The angle of attack changes during a flight as the pilot changes the direction of the aircraft. It is one of the factors that determine the aircraft's rate of speed through the air. See video on Angle of Attack for a demo.




*The angle of attack is the angle between the chord of the airfoil and the relative wind.*

Notice the clouds in the picture to the right. The positive angle of attack of the wing pushed air down into the clouds behind the airplane thus pushing the airplane up. The airplane did not create the trail by flying through the clouds. The trail was created by the deflected relative wind bouncing off the bottom of the wing.

The increase in angle of attack increases lift up to a point. The angle of attack forces the relative wind hitting the airfoil down. (The relative wind is the flow of air past an airfoil relative to the path of flight. It is parallel and opposite in direction to the aircraft's path of flight.)

By Newton's third law of motion (equal and opposite reaction), the wing is pushed up (lift). Lift is not created without a trade off. The relative wind also pushes the wing backward (induced drag).

At some point, the force of drag is greater than lift as the angle of attack increases. The aircraft will stall (stop flying and start falling), without enough lift. See What Makes an Airplane Stalls video.

Depending on the angle of attack, there will be a force backward (induced drag), and a force upward (lift). The amount of force depends on the angle of attack. If the angle of attack is small, the drag and lift are comparatively small.

Bernoulli's principle helps explain the efficiency of a wing design. Bernoulli's principle explains that there is a difference in air pressure above and below the wing. Faster air moving over the top of the wing creates low pressure, which creates a "pulling" type of effect. Slower air moving underneath the wing creates a higher pressure which provides a "push" upward on the wing. See short demo video HERE using an airplane's wing. And, a quick demonstration with bathroom tissue and a leaf blower HERE.

**Materials:**

- "airfoil" pictures which can be used as a transparency showing the cross section of an airplane wing with air traveling over and under it (included)
- "Four Forces of Flight: Illustrations" pictures which can be used as a transparency (included)
- computer with Internet and projector (for use with videos)
- overhead projector (or alternate method of displaying transparency information)
- balsa power plane kits (provided by CAP for the students)
- Frisbee (optional, but good for demonstration)

**Lesson Presentation:**

1. Pre-assemble a balsa power plane to show the students. Read the black titled section on Assembly of Guillow's Sky Streak plane, as there are tricks you need to know (such as wing position, fin issues, and lubrication of the motor- which is the rubber band).

2. Tell the students they will be building their own plane today and will be experimenting with its flight. So, ask students if they can explain how an airplane flies. Tell them that they will be able to explain the forces that act upon things that fly as they go through this lesson.

3. Show the "Forces of Flight: Illustrations" transparency/information (included), and briefly describe each force's effect on an airplane. (See background information for explanation of the forces of flight.) Explain lift and gravity last.
   -- You can also show the forces of flight video with simple demonstrations.
   -- To help explain the forces of flight, make comparisons to traveling in a car. For example, a car's engine provides the "thrust" needed to move it forward. An airplane's engine and propellers create its thrust.

   Lift, drag, and angle of attack are easily observed by sticking your arm out of the car window while riding with hand extended and fingers together. Imagine your arm is now a wing. Rotate your hand to change the angle of attack. At each angle, notice the relative wind hitting your hand. When your hand is parallel to the relative wind (angle of attack = zero degrees) the

relative wind puts pressure on the leading edge of your wing only. Keeping your hand in one place is fairly easy. This is the point where lift and drag are both lowest. Rotate your hand so your thumb is higher than your pinky finger (angle of attack is greater than zero), and your wing finds lift. Notice the relative wind also pushes your hand back (induced drag). Continue rotating your hand and you will find an angle of attack where the drag pulling your arm backwards is greater than the lift. Your wing has stalled.

Now rotate your hand the other direction so that your thumb is lower than your pinky finger. Notice the same rules apply. The angle of attack is negative and the relative wind now hits the top of your hand. The lift is pushing your hand into the ground! A pilot can change the aircraft's angle of attack to fly both up and down through the air. To remain in the air, the aircraft will need lift to continually overcome gravity; therefore, the angle of attack for normal flight is greater than zero. Aircraft wings are designed and built with a positive angle of attack for this very purpose.

3. Show the airfoil transparency with diagram of the air flow over the airfoil. Explain that the curved edge of a Frisbee serves the same purpose as the curved front of the wing. This particular shape is called an airfoil, and it helps create lift. Further explanation should be given: Airplanes are able to fly because of the movement of airflow above and below their wings. As the engine and propellers work together to provide thrust and move the plane through the air, air flows above and below the wing. The angle of attack affects the altitude of the plane, or the plane's lift. Another factor that aids in lift is Bernoulli's principle, which relates to the pressure difference that occurs between the area over and under the wing. Air molecules traveling over the top of the airplane move faster than those moving below the wing. This fast movement of air causes a low pressure above the wing, which creates a "pulling" effect. The slower moving air under the wing creates a higher pressure that creates a "pushing up" effect. Both the pull and push forces work together to keep the plane lifted into the air.

4. Ask students what keeps a car on the ground. (gravity) Ask students to explain why gravity keeps a car on the ground, but not an airplane. If students say a car cannot go fast enough to take flight, dispel that thought by telling them that a small, lightweight aircraft can take off at speeds around 60 miles per hour, and a car can certainly go faster than 60 mph! A German plane was developed in WWII that could take off at about 25 miles per hour! Speed is not the reason a car doesn't lift off of the ground. It has to do with design, specifically wings that generate lift! Airplane wings generate most of the lift for airplanes.

   Cars were not designed to fly. Yes, the forces of drag and lift act on a car, but due to the design of cars and the "angle of attack" of their parts against air, they do not take off. In fact, to try to keep race cars, like Formula One cars, from coming off the ground, an inverted airplane wing is located in the front and back of the car. This improves "downforce," which adds more weight on the tires. (Even some regular automobiles utilize a type of inverted wing to correctly and efficiently direct air flow.) This doesn't mean, though, that race cars will never come off of the ground. The right speed and angle of attack (remember, racetracks are not always flat) could

it to lift off of the ground, but it won't stay in the air for long (no continued thrust and wrong angle of attack)! (See short video of flying Formula One car that crashes, but driver is unhurt.) ***** See Formula One aerodynamics video that compares the angle of attack of the wings of the car with the angle of attack of the wings of an airplane! Cool!**

5. Using the bottom picture on the "Forces of Flight" transparency, point to the different arrows and ask the class to name the force indicated by the arrow.

6. Provide a plane kit to each student. Guide students through the building process according to the directions provided in the kit. Or, show a quick video on how to put together the balsa power plane HERE. Watch, also, how to wind the rubber band in a clockwise direction. ***Remind the students to be careful as the balsa wood will break easily! Once the planes are made, have students write their name on their plane, and decorate, if so desired.

7. Have students hold their assembled plane with the propellers pointed toward the front of the classroom. Call out each of the four forces of flight and ask students to orient their planes correctly to show the effect of the force. For example, when you say "thrust," students should move their plane forward. When you say "drag," students should move their plane back. Remind students that each force is necessary in order for airplanes to fly.

8. Ask the students if they know what the motor is that turns the propeller to provide thrust. It is the rubber band! When the rubber band is twisted tightly "elastic potential energy" will be created. When the rubber band is released, "kinetic energy" will be created which will turn the propeller and provide thrust. Demonstrate the clockwise winding of the rubber band and releasing to demonstrate how the 'motor' will turn the propeller and provide the thrust for flight. (Only wind a few times for an inside demo.) Show a very short demo launch video, illustrating how to hold the propeller and let it go while thrusting the plane forward in a smooth and level position.

9. Take the students outside with their planes to demonstrate the forces of flight and experiment with flight. * Go over safety issues with students before flying. - Use safety goggles, if available. Remind the students not to fly airplanes in close proximity to other students and be vigilant at all times.) You may wish to take some tape outside to help with any necessary flight repairs.

10. While the students practice flying their plane, have them discuss amongst each other which forces are and are not working well. If the plane is shooting straight up and then back down, they probably are using the wrong angle of attack in their throwing of the plane to start. Help them determine what adjustments they need to make to their airplanes to make them fly longer and farther- trying to balance these four forces. Continue flying until time to go back inside.

**Summarization:**

Ask students to share their flight experiences. Ask them to identify problems they encountered with their flights and any solutions at which they arrived. Ask students the following review questions.

- What provided thrust for their airplane? (the rubber band and propellers)
- What eventually brought the airplane back to the ground? (gravity)

- What force worked against the forward motion of the airplane? (drag)
- What force helped hold the airplane in the air while thrust was being generated? (lift)
- Ask students if they have any ideas as to why lift occurred with the airplanes even though the wing is not curved like an airfoil? (orientation of the wings to the air - angle of attack)

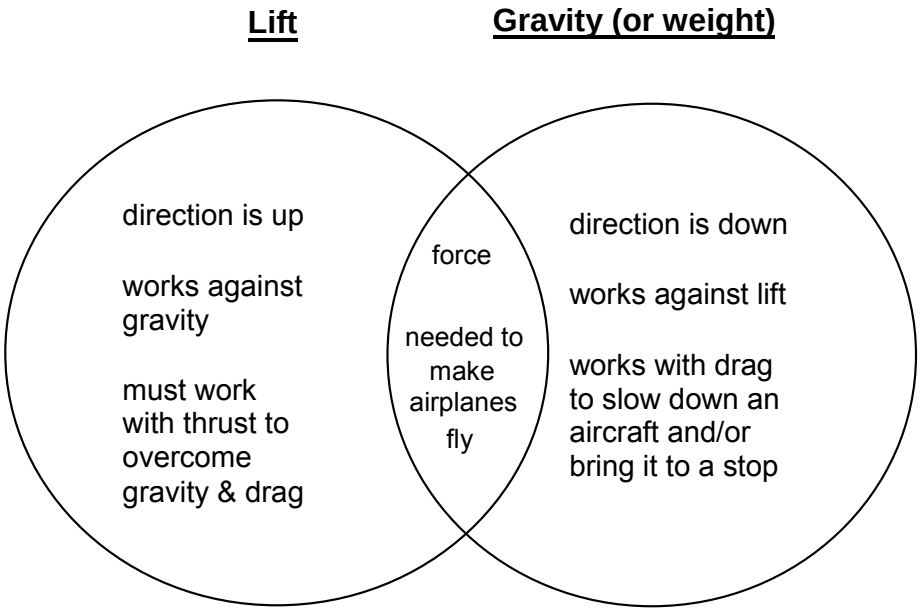
**Character Connection:** Tell students that just like there are forces that affect flight, there are forces all around us that affect our lives. Some of the forces are good and some bad. For example, the force of peer pressure might cause us to do something we will regret if peers are pressuring us to do something wrong. Our parents, teachers, coaches, and other adults in our lives can be a strong force in our lives to encourage us to do good things. Media (television, movies, magazines, etc.), can be a force that influences our decisions. Encourage students to be aware of the forces around them and make good decisions that will positively impact their lives. Encourage them to be a positive force to motivate others to make good decisions, as well.

**Drug Demand Reduction (DDR) Connection:** See page 10.

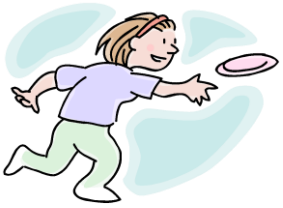
**Assessment:**
- teacher observation
- construction and flight of airplane
- "Four Forces of Flight" worksheet (optional)

**Additional activity ideas to enrich and extend the primary lesson (optional):**
- Have students complete the "Four Forces of Flight" worksheet.
- Present the following information about Frisbees:
  Many people claim to have invented the Frisbee. They got their start in New England colleges during the 1800s when students would fling empty pie tins from the Frisbee Baking Company for fun. In 1948, a Los Angeles man named Walter Frederick Morrison invented the first plastic version that flew further and with better accuracy than the pie tin.
  Just like the shape of an airplane, the shape of a Frisbee has a great deal to do with its ability to soar through the air. A Frisbee is an airfoil, just like the wing of an airplane is an airfoil. An airfoil-shaped body moving through the air produces a force called lift. A Frisbee's spinning action creates stability for the Frisbee, the same way that airplanes and birds have tails, and rockets have fins to help keep them stable during flight.
  Activity: Have students demonstrate the four forces of flight with a Frisbee. Have them experiment with Frisbees of different shapes and sizes and draw reasonable conclusions.
- Divide students into small groups. Have groups determine other ways that they can demonstrate the four forces of flight. Then, let the groups share their ideas with the class.
- A really good 9.5-minute video is found HERE that goes from the construction of a plane's parts to make the plane, to how the parts work to make the airplane fly, to an actual flight, maneuvers in the air, and a landing. Worth the students' viewing, if there is time.

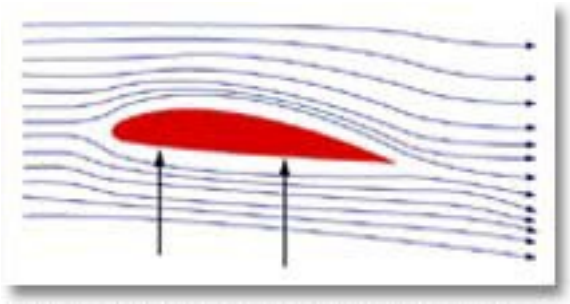
- Have students compare and contrast the four forces of flight on an airplane in a Venn diagram. Remind students that each force has an opposite force that works against it.
  Example:




**Associated Literature and Websites:**



- *Frisbee* by Dr. Stancil E. D. Johnson (Amazon)
- *Fabulous Frisbee* by Dorothy Childers Schmitz (Amazon)
- The Four Forces Of Flight - NASA SCI Files
- Forces of Flight by Smithsonian Education
- Read more about the aerodynamics of Formula One cars.
- Read "The Four Forces of Flight" (NASA).



Cross Section of an Airfoil (such as an airplane wing)

Source: Why Can't We Fly a Plane to Space?

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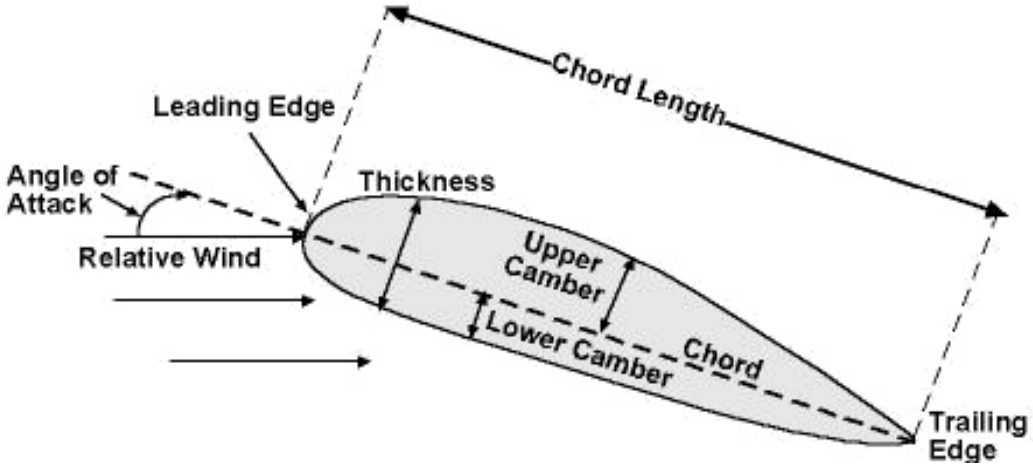


The **angle of attack** is the angle between the chord of the airfoil and the relative wind.

Source: Civil Air Patrol

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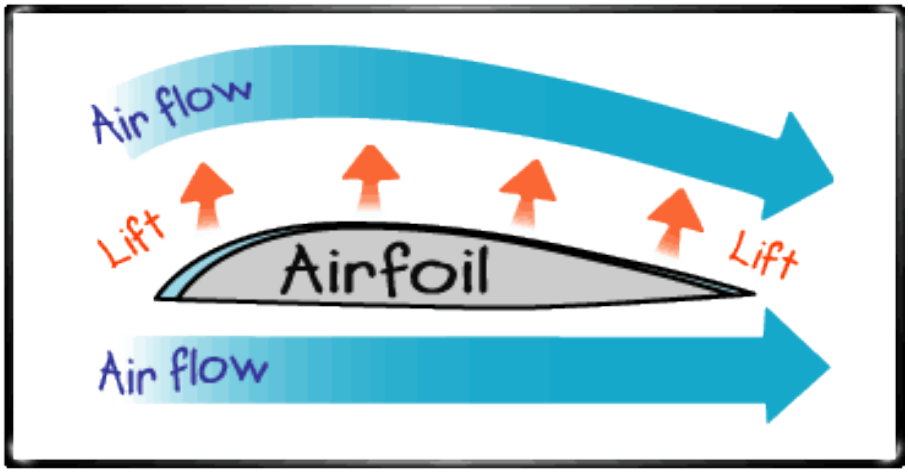
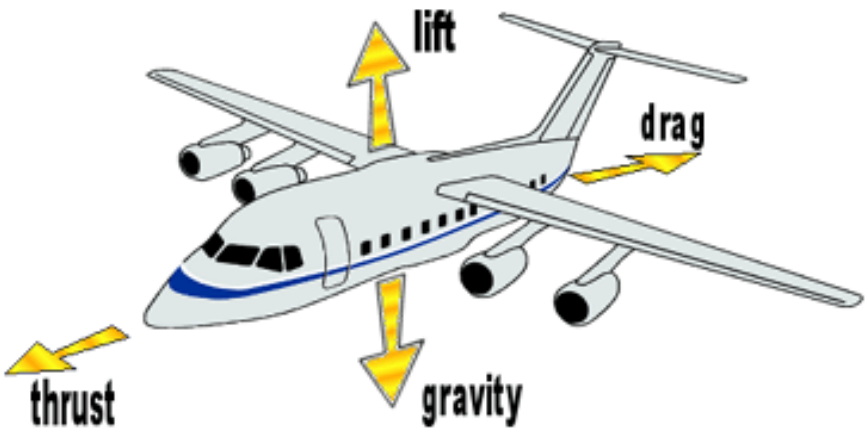


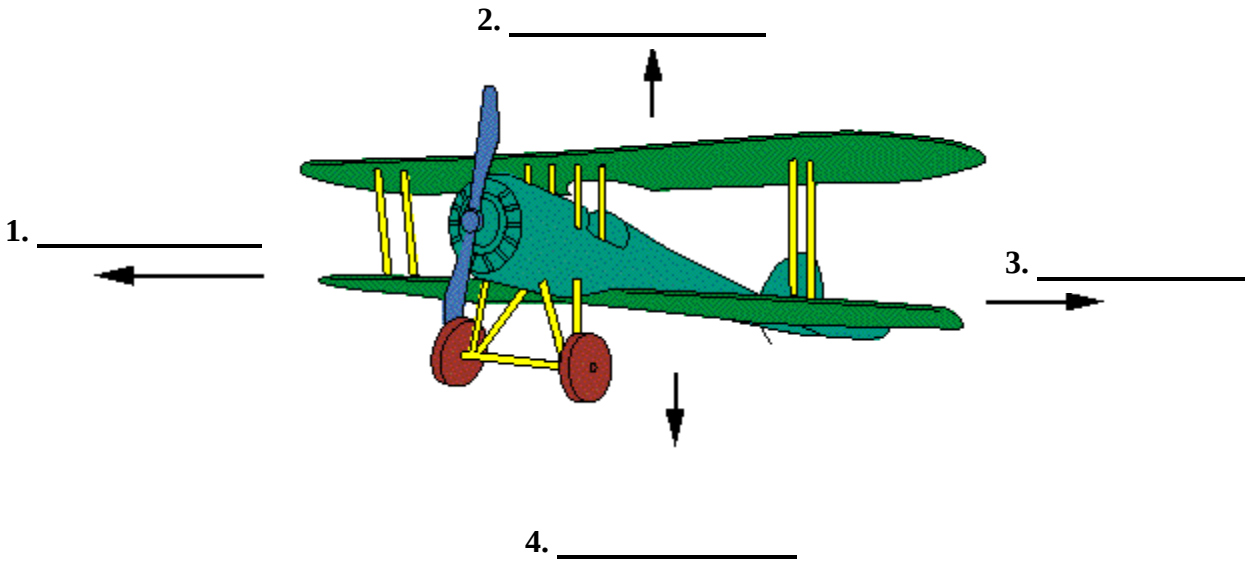

Airflow Above and Below an Airfoil (such as an airplane wing)

# FORCES OF FLIGHT: ILLUSTRATIONS (transparency)

| Four forces of flight | |
|---|---|
| **Lift** - upward<br>**Drag** - down and backward<br>**Weight/Gravity** - downward<br>**Thrust** -forward |  |

Above picture source: NASA: UEET Dynamics of Flight

**Name of the force of flight represented by each arrow.**



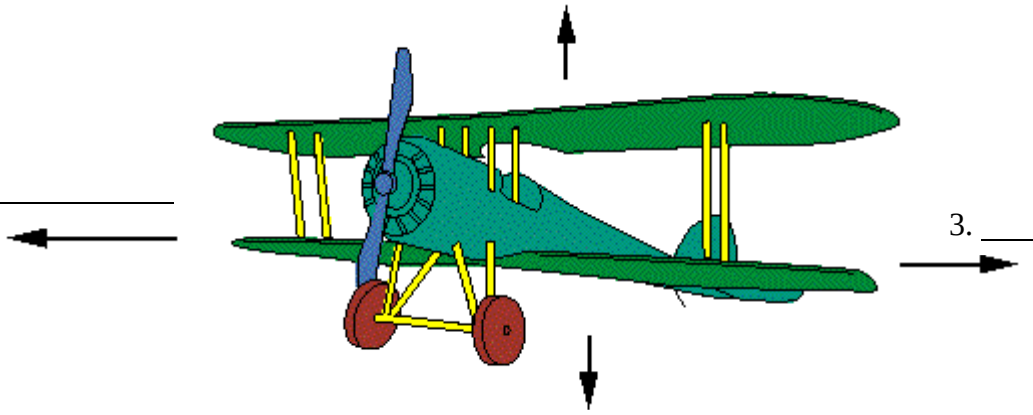

Source: NASA Explores

# FORCES OF FLIGHT Name _____

**Write the name of the force of flight represented by each arrow.**

2. _____

1. _____



3. _____

4. _____

**Write the letter of the correct term beside each description. You may use a letter more than once!**

**A. Lift B. Drag C. Thrust D. Weight (or Gravity)**

_____ 1. The special shape of the wings and how air moves over the wings creates this force.

_____ 2. This is a force that moves the object in the direction of motion. An engine or a propeller can create this force.

_____ 3. This force is the air resistance affecting a moving object. It seeks to slow down the object.

_____ 4. This force always pulls downward.

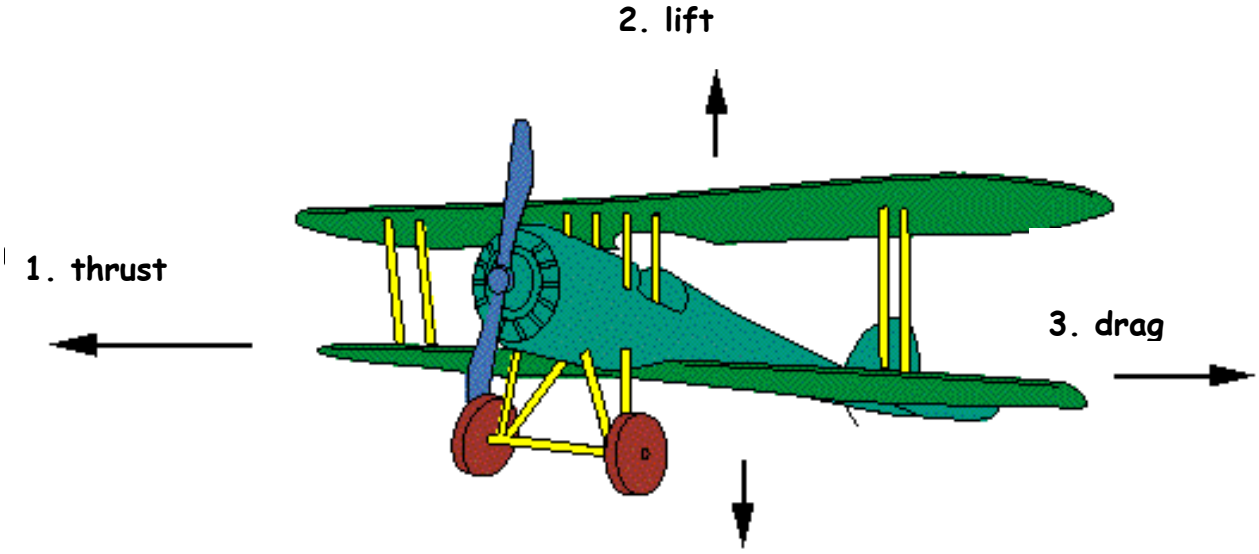
_____ 5. This force is opposite of drag.

_____ 6. A demonstration of this force is putting your hand out of the window of a moving car and feeling the air pushing your hand back.

_____ 7. This force is the opposite of gravity or weight.

# Forces of Flight Answer Sheet

**Write the name of the force of flight represented by each arrow.**




**Write the letter of the correct term beside each description. You may use a letter more than once!**

**A. Lift B. Drag C. Thrust D. Weight (or Gravity)**

**__A__** 1. This force is created by the special shape of the wings and how air moves over the wings.

**__C__** 2. This is a force that moves the object in the direction of motion. An engine or a propeller can create force.

**__B__** 3. This force is the air resistance affecting a moving object. It seeks to slow the object.

**__D__** 4. This force always pulls downward.

**__C__** 5. This force is opposite of drag.

**__B__** 6. A demonstration of this force is putting your hand out of the window of a moving car and feeling the air pushing your hand back.

**__A__** 7. This force is the opposite of gravity (or weight).