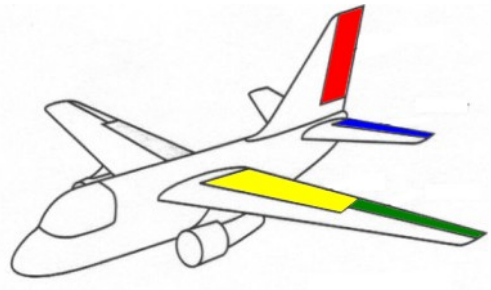
Forces and Flight

(This activity is based on "The Paper Airplane Book" by Seymour Simon)



- Airplanes use forces by moving air to fly
- Flowing air makes **drag forces** (against motion) that depend on the shape and orientation of the object.
- Some of the drag from moving air is converted to an upward **lift force** when the nose of the plane is tilted up
- **Bernoulli's principle** also provides lift. A surface where air moves by faster (top of the wing) feels lower pressure.
- Airplanes use movable flaps to control lift and drag forces and to make turns.

Part 1: Drag and Lift

1. Drop, from standing, at the same time, a flat sheet of notebook paper and a crumpled up piece of paper.

Which one hits the ground first? _____

What forces are acting on the falling paper? In which direction?

Which force is the same for both the flat sheet and the crumpled blob? _____

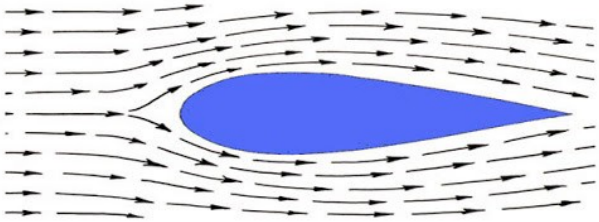
Which force is different? _____

Is it bigger or smaller for the flat sheet?_____

2. How else could you fold the paper to make it fall as fast as possible? Try different shapes. When testing two shapes always start the bottom of the objects at the same height.

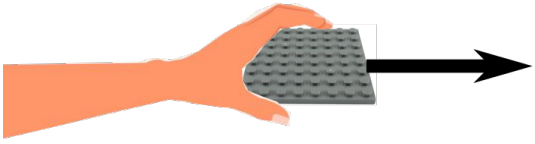
What is the best shape you could find for hitting the ground first?

Air resistance (or **drag**) is a force that acts **against the direction of movement**. The strength of air resistance depends on the shape of the moving object. "Stream-lined" shapes (narrower in front and wider in the middle) help decrease drag.

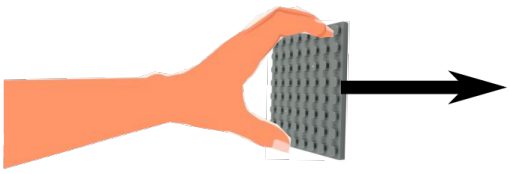


What man-made or natural objects can you think off that have a streamlined shape? Why is it helpful for them to have that shape?

3. Now let's try feeling drag directly. Drag forces are produced by any flowing fluid (air or water). Place your Lego plate under water. Holding it by the sides, pull it rapidly through water with the flat side parallel to the ground. Then pull it with the flat side facing forward.



narrow side forward



flat side forward

In which direction did you feel more drag pushing back from the water? _____

The orientation of the object can make the drag force small or large.

4. Still holding your Lego plate by the sides, try pulling it through water while it is oriented diagonally, with the front end higher

front end up

front end down

Do you feel an upward or downward push by the water on the plate, in addition to the backward push you felt before? Circle one:

upward downward no vertical force

5. Now try pulling it through the water with the front end tilted down.

Do you feel an upward or downward push by the water on the plate?

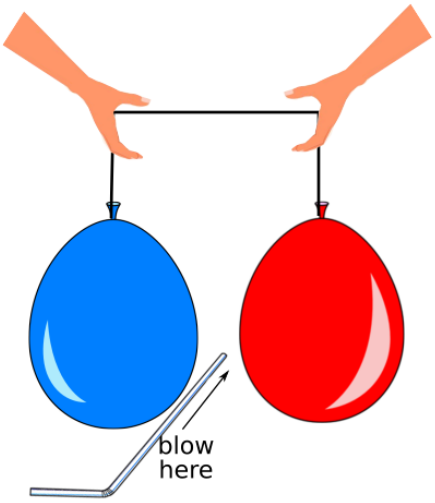
upward downward no vertical force

The **lift force** pushes up on an airplane and prevents it from falling. Tilting the airplane nose up will result in a lift force from the air that flows past it.

What would happen to an airplane if it stopped moving. Would it still feel a lift force?

Part 2: Bernoulli Principle

Now let's explore another source of lift in flight.



1. Blow up two balloons so they are about half-way inflated. Tie a string with one end to each of them.
2. This step is easiest with a partner, but can be done by yourself.
One partner should hold the balloons by the string so they are hanging motionless, about 1 inch apart. The other partner will use the straw to blow directly between the two balloons.
Predict what will happen first. Will the balloons….

Come together? Spread apart? Keep hanging still?

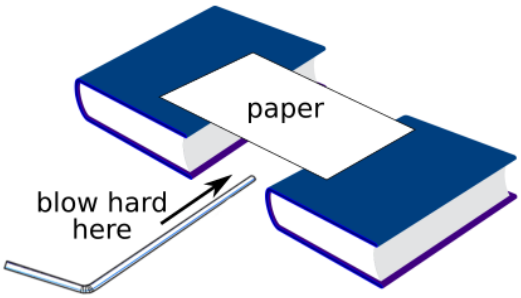
Now blow between the balloons and see what happens!

What happens? Circle one:

sheets come together sheets spread apart nothing

What you just saw is called the **Bernoulli effect**. The pressure (outward force) in a moving fluid (like air or water) is lower wherever the fluid is moving faster. Low pressure between the balloons and higher pressure outside them means that the balloons get pushed together.

3. Another demonstration of Bernoulli's principle: put a sheet of paper over the gap between two books.

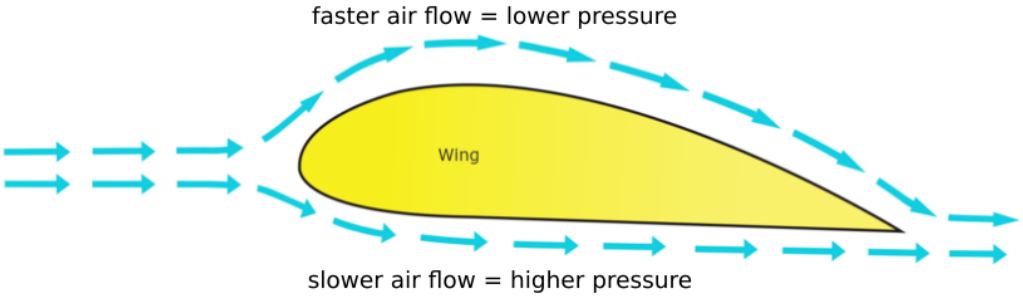


What will happen when you use the straw to blow through the gap underneath the paper

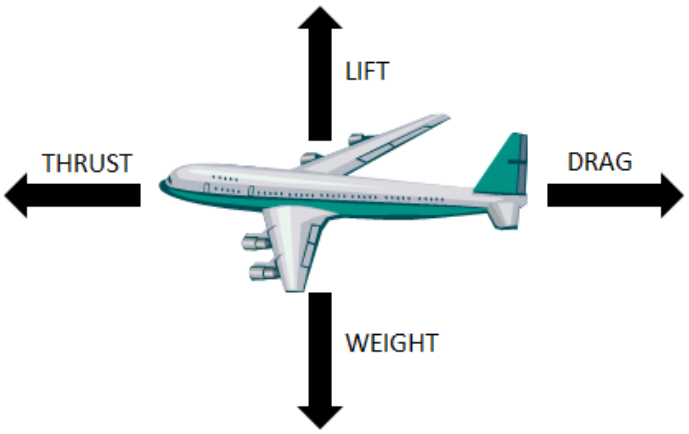
Prediction:

Observation:

Airplane wings are designed to be more curved on top than on the bottom. Air has further to go over the top and ends up moving faster. Less pressure on top and more pressure on the bottom translates to an over upward lift force!

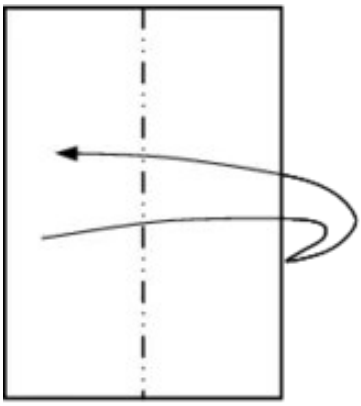
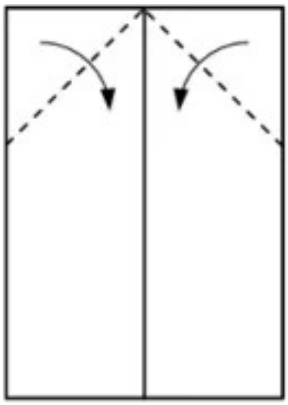
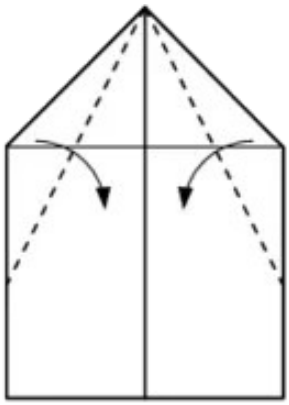
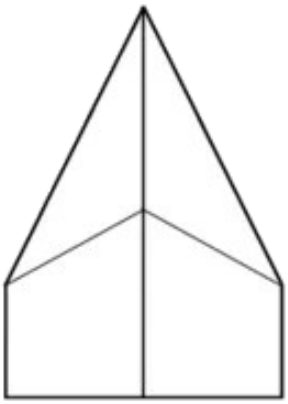
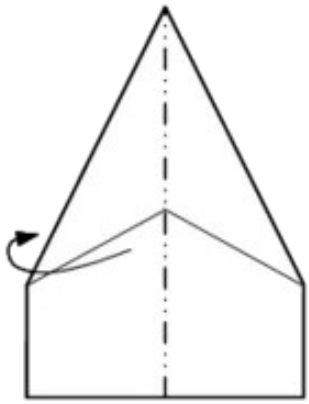


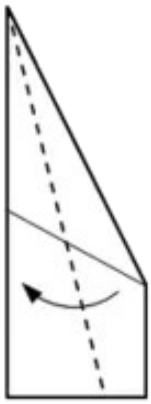
Now you know the 4 main types of forces acting on a flying airplane (or bird):
1) **Gravity** (weight) pulls down.
2) **Lift** forces pushes up.
3) **Drag** forces push backward.
4) **Thrust** is a force that pushes the plane forward. This can be produced by propellers or jets.



Part 2: Paper Airplanes

1. Make a simple "Dart" paper airplane following these steps:

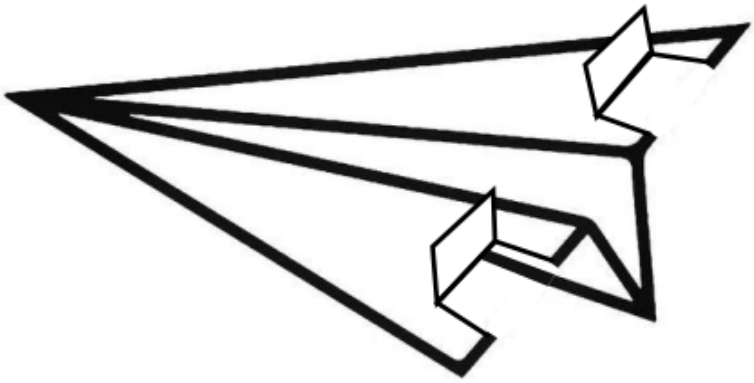








Use a piece of tape to secure the top of the plane so that it doesn't open.

2. Try out your paper airplane. Estimate how far it flew. _____ steps
Try a few more trials to get a sense of how it flies.

4. Cut 1" wide flaps in the back of each airplane wing.



Make a prediction: how will the plane's flight change if you tilt both flaps slightly up?
(Hint: hold the plane loosely in the middle and try pushing on the flaps with your finger. Think about what that force will do to the plane.)

Test your prediction. What did the plane do?

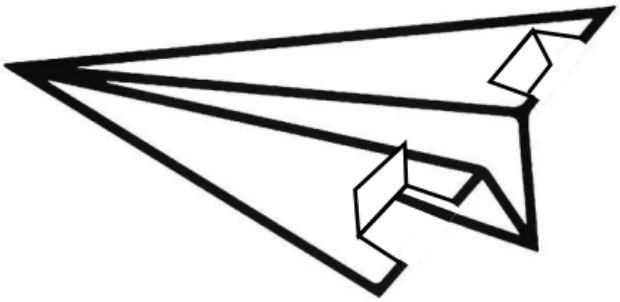
In addition to slightly increasing the lift of the plane, the upward tilted flaps also increase what other force? Drag gravity thrust

What happens if you turn the flaps up too far?

Now predict what will happen if you push both flaps downward:

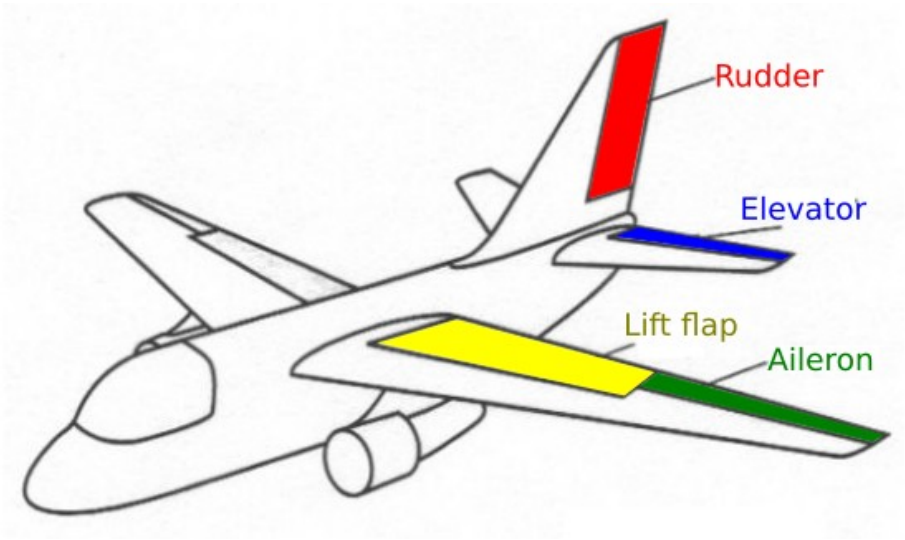
Test your prediction. Were you right?

Finally, predict what will happen to the plane if you tilt one flap slightly up and one slightly down.



Were you right?

Real airplanes control their flight with movable flaps on the wing and tail.

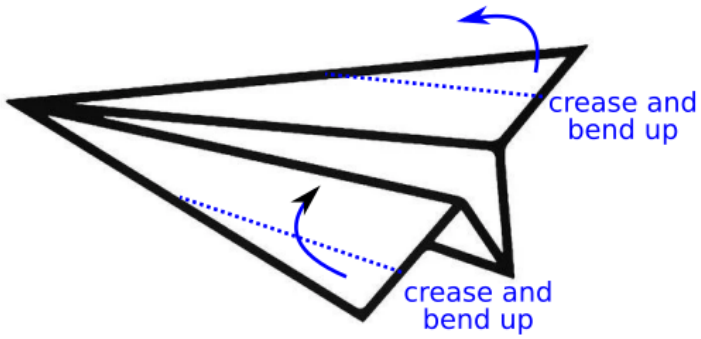


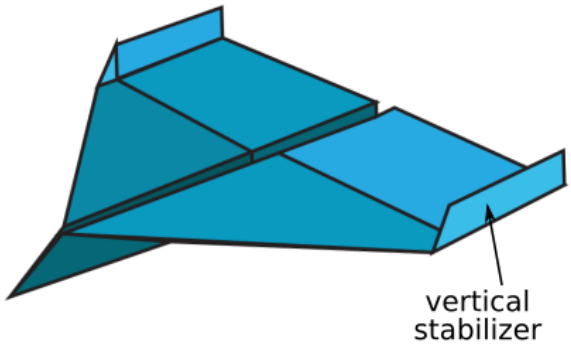
Lift flaps on the wings help increase lift during take-off and landing.
Aileron flaps at the edge of the wing allow the plane to roll left or right.
Elevator flaps at the back of the tail let the pilot point the plane's nose up and down to change the height of the plane.

How did you use your flaps to mimic some of the different controls on a real airplane?

5. The **vertical stabilizer** on the tail of a real airplane makes the plane more stable and less likely to spin around. Let's add some vertical stabilizers to your plane.

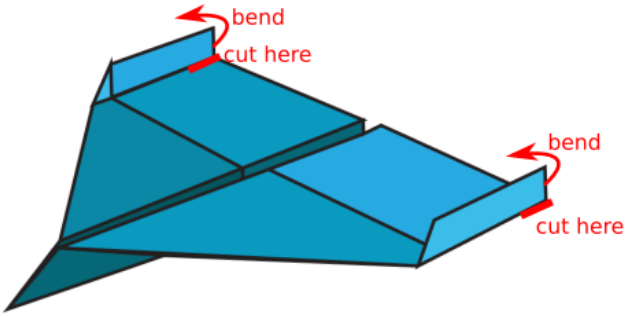
Flatten down the flaps. Make "vertical stabilizers" on your plane by folding up the edges of the wings. Make sure your folds are parallel to the center line of the plane.





Do you notice any effect on the flight of your plane?

6. Cut 1 inch flaps in the back of the vertical stabilizers.



Bend both flaps to the left. Predict what the plane will do:

Were you right?

Now bend both flaps to the right. Predict what the plane will do:

Were you right?

In the diagram of a real plane above, where is the vertical stabilizer?

The flaps you just made on your plane represent what flaps on the real airplane?

Lift flap Aileron Elevator Rudder