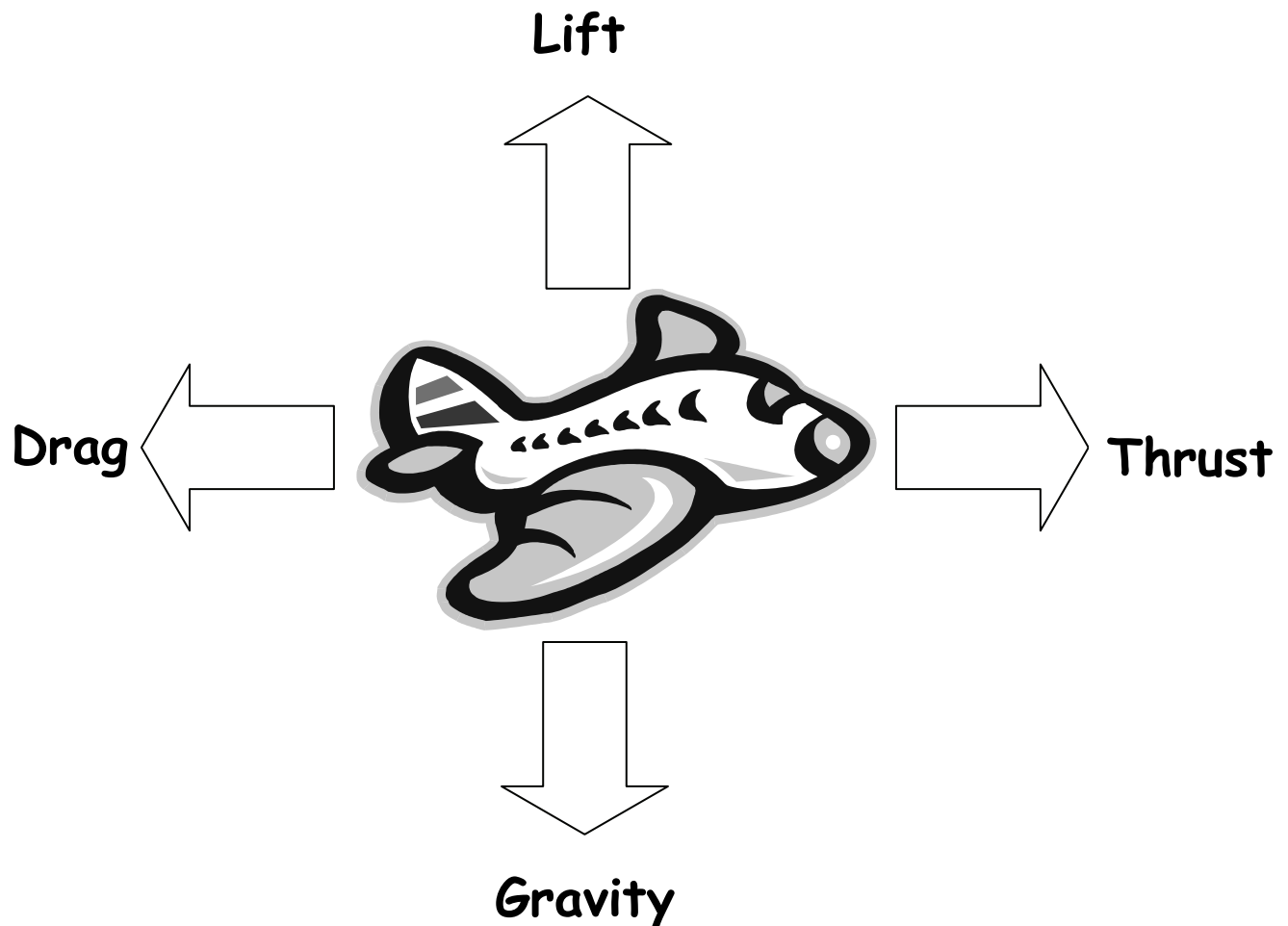




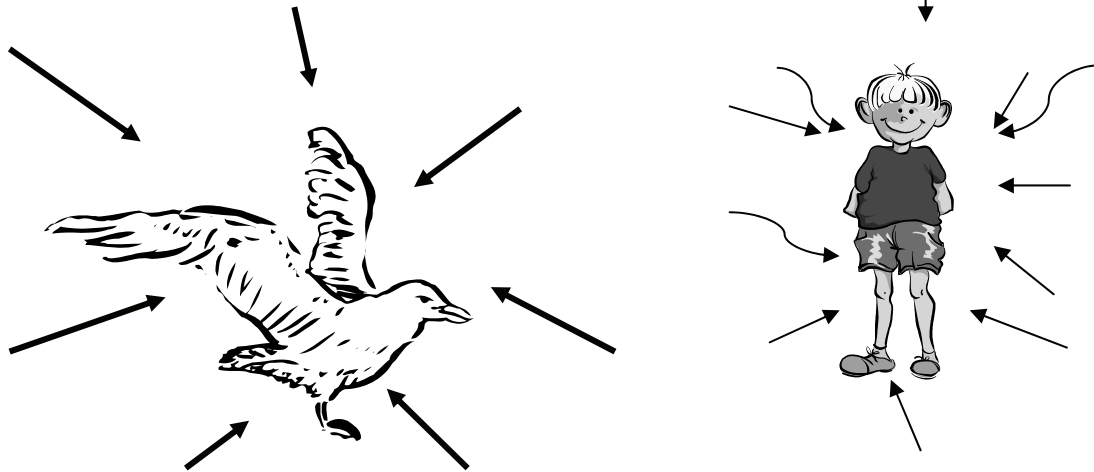
## May the Forces Be With You Experiments

### How an Airplane Flies

There are four forces that must be either created or overcome to make an airplane fly: **lift**, **thrust**, **drag**, and **gravity**.



How these forces are balanced determines how the plane will behave. Upward forces (lift) must be greater than the downward forces (gravity) for any object to get off the ground. In order to move forward, an airplane must have greater thrust than drag. Airplanes use engines to supply the forward force of thrust.



Air is pushing on all objects (including you) at all times. Usually the push is equal on all sides, so that you do not notice it. This push by air is called **air pressure**. In 1738, Daniel Bernoulli, a Swiss scientist, discovered the link between wind speed and air pressure. When air moves, it has less pushing power and does not press on objects as much as still air. The higher the wind speed, the lower the pressure. Moving air has less pushing power than still air.

**Bernoulli's Theory: in a moving stream of air, the pressure is always lowest where the air stream is fastest and greatest where the air stream is slowest.**

**Try the following experiments:**

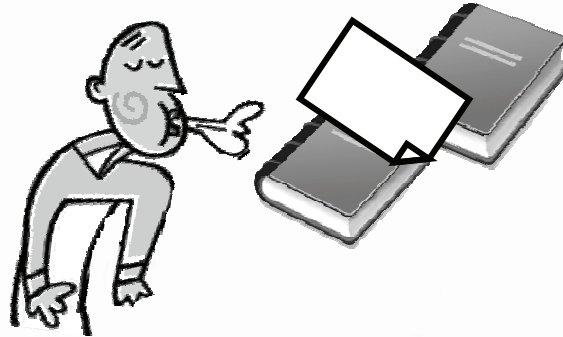
### **LIFT**

Hold a piece of paper just below your lower lip. Blow steadily across the top. What happens? Your breath moves the air above the paper, which reduces the pushing power of that air. The air pressure underneath the paper remains normal. The air pressure is stronger underneath the paper and lifts the paper.

Fold a strip of paper about 8 inches long and 2 inches wide into a bridge. Blow under the bridge. When you blow under the bridge the air is rushing through the gap. The speed of the air is high, making the pressure low.



Place two large books about 4 inches apart. Lay a piece of paper over the books forming a bridge. Try to make the paper float away by blowing underneath the paper bridge. What happens?



Hold two sheets of paper in front of your face and try to blow them apart. The moving air you blow between them should draw the sheets of paper together instead of separating them.



Using lightweight string or thread, suspend ping-pong balls about 2 inches apart. Make sure that they are hanging still. Using a straw, blow between the two balls. What happens? The air that was blown between the balls has less pushing power than the air on the side of the balls. The pushing air or the air on the outside of the ping-pong balls makes them move together.

***Lift is an upward force that acts against gravity because of a partial vacuum created above the surface of an airplane's wing causing the wing to be lifted upward. Lift is produced by (a) the difference in the speed of air flowing over the wing surfaces and (b) the angle of attack.***



## **THRUST**

Imagine you are on a skateboard. You start to move forward to step off the board. What happens? As you step forward and off the skateboard, it moves backwards. Why? For every force in one direction there is always an equal force in the opposite direction.

Blow up a balloon and hold the opening tightly. Release your hold on the opening. What happens? What direction does the air move? What direction does the balloon move?

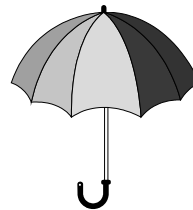
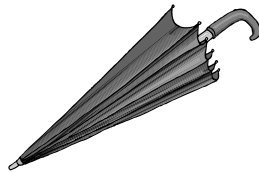


Attach a small lightweight toy to an inflated balloon. Release the hold on the balloon opening. Which direction does the toy move? Which direction does the air move?

***Thrust is a force created by a power source, which gives an airplane forward motion. Engine-driven propellers, jets, or rockets may produce thrust.***

## **DRAG**

Have a student run with a closed umbrella behind him. Observe the amount of drag on the umbrella. Repeat with the umbrella open. How does the amount of drag change? Explain.



Drop two identical sheets of paper (one flat, one crumpled) from the same height. Observe the effect of air resistance on the rate of fall. Why is there a difference?

Drag a clothespin through water. Attach a bottle cap and repeat. What happens? How does shape influence drag? What are the implications for designing airplanes?

***Drag is the resistance the air offers because of friction, which slows the forward movement of an airplane through the air. It is a backward force that works against thrust. Streamlining the shape of an airplane may reduce drag.***



## **GRAVITY**

Ask a student to jump in the air and stay there. Why is this impossible? Discuss what would happen without gravity.

### **Measuring the Force of Gravity**

1. Tape a long strip of paper (at least 4-5 feet in height) on the wall to the floor.
2. Tie a strip of very strong elastic to the handle of a bucket or pail.
3. Fill the bucket with sand and drop it from the height of the strip of paper on the wall. Mark the distance it fell on the strip of paper.
4. Fill the bucket with another material such as water. Repeat experiment and mark how far it falls.
5. Fill the bucket with ping-pong balls. Repeat the experiment and mark how far it falls.

Discuss which material is most affected by gravity, and which is affected the least. How does this information relate to flying? How might you measure the actual force of gravity pulling down on each kind of material?

Now do the following:

1. Weigh the pail
2. Weigh the material in the pail
3. Subtract the weight of the pail

Discuss the idea that the pull of gravity is equal to the weight of the object; that weight is a product of gravity.

**Gravity is the force which pulls downward on the airplane. The weight of the airplane is produced by the attraction of gravity.**

