Paper Airplanes

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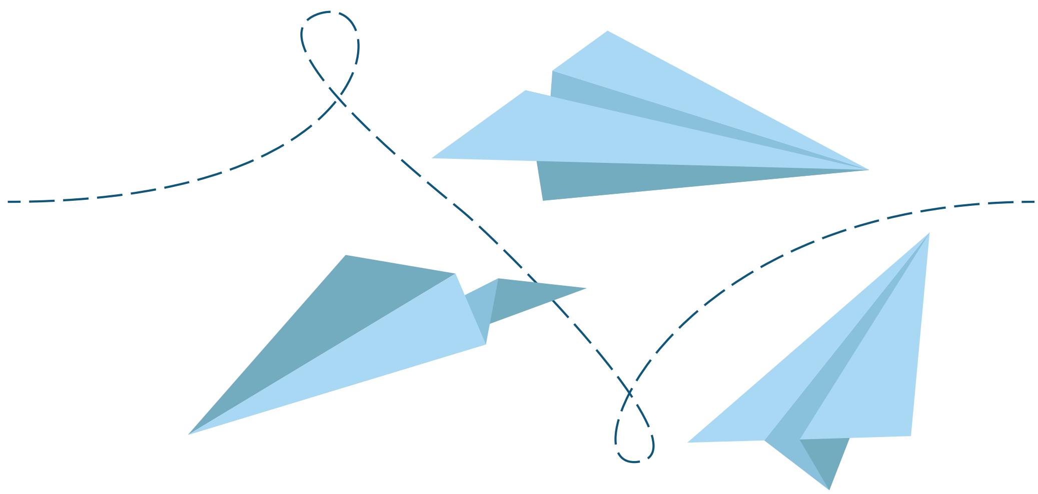

FLIGHT.

It's the stuff of American heroes. Charles Lindbergh was the first person to fly solo across the Atlantic Ocean in 1927. Amelia Earhart was the first woman to fly across the Atlantic in 1932. The Mercury 7 astronauts came from airplane flight backgrounds to become the first Americans in space, starting with Alan Shepard in 1961. Were any of you born in 1961? We have done amazing things with flight in the last 100-plus years since the Wright Brothers first took to the skies in 1903.

Let's learn about flight by folding and experimenting with paper airplanes. The basic lesson is for students in grades 3-6. For older students (in fifth and sixth grades or older), you may wish to add one or more of the advanced lessons at the end. Paper airplanes are fun for students of all ages!

YOUR CLASS WILL DO THIS EXPERIMENT IN TEAMS, teams of 4 or 5 students are ideal, depending on the size of your class. It's okay to have smaller teams.

For the basic Paper Airplanes lesson you'll need to prepare the following supplies:

EACH TEAM will need:

- Colored paper for printing copies of paper airplane templates. A random mix of colors is fun. White paper is okay. If you use white paper, you may enjoy decorating your planes with magic markers.
- Two plain sheets of paper for each student. This paper can be scrap paper from your recycle bin.
- One or two printed (color if you have it) copies of each of the paper airplane template per student, plus a few extras.
- Plain copies of paper airplane folding instructions, one per group of students. You can also project the instructions onto a screen to save paper.
- Paper clips, various sizes and/or colors (several for each student).
- Scotch tape. (One dispenser for each group.)

Pre-experiment discussion.

[Recommended time: 15 minutes]

How did we know that we could fly? Let's think about this.

- What kinds of things fly? (Birds, planes, balloons, rockets, insects, bats …).
- Which of these are natural and which are man-made?

It's from observing animals that we got the idea and inspiration for man-made flight.

- Can you name different types of flight? (Flapping, fixed wing, rotary wing, rocket-propelled, gliding)
- What about different phases of flight? (Cruise, take-off, landing.)
- What makes these things go? (Engines, gravity, muscles.)

Take a look at some examples of flight in nature (Show the three bird videos from downloads). What kind of man-made flying things fly like each of these birds?

Now let's talk about the forces, on both birds and airplanes, that allow them to fly.

Let's talk about gravity and lift first [show Forces in Flight slide]. Gravity pulls things down towards earth, while lift pushes a plane's wings up in the sky. We cannot do much about gravity, but we can create lift. Think of an airplane wing. As a wing travels through the air, its front edge is angled up a bit. Air hits it, slows down, and creates an upward pressure. At the same time, air on top of the wing speeds up, lessening pressure and creating an upward suction.

Lift. Experiment 1

[Recommended time: 5 mins]

Everyone spread out, take a plain sheet of paper and put it between your hands, with thumbs pointing to the left or right. Now spin in the direction of your thumbs, keep spinning, and remove your lower hand. The paper does not fall! Point your thumb up a little more and feel the lift increase.

Paper Airplane #1. The Delta.

[Recommended time: 15-20 mins]

Let's make our first paper airplane. Each team of 4-5 should have a set of instructions and each team member should have a paper airplane template. This plane is called the Delta– it should fly straight and smooth.

Show the Paper Airplane Folding Video, which you will find under downloads. It includes hints for optimal folding and flying of paper airplanes from the Guinness World Record Holder for paper airplane flight.

Pass out the Delta templates and have the students fold their airplanes. Each group goes to a different part of the room (to their "runways") and takes turns flying their airplanes. Afterwards, have a group discussion with the whole class, discussing their successes and room for improvement based on the Paper Airplane Folding Video.

Afterwards, some students may wish to fold another Delta and try for improvements. Some students may wish to add paperclips as weight, to improve their planes. For example, if a plane nose-dives, it may help to add a paperclip to the tail.

Lift/Gravity Experiment 2

[Recommended time: 5 mins]

Crumple up a plain sheet of paper, of the same weight as your airplane paper, into a ball. Since each sheet of paper weighs the same, we know gravity is acting the same on the ball and your airplane. Now holding the airplane in one hand, and the ball in the other, launch them both gently forward with the same amount of force. The ball drops to the floor because there is nothing to hold it up. But the plane has wings that create lift and counter gravity.

Think about the video of geese taking flight. In their case, it's the flapping that creates lift. When the birds draw their wings up, they are more pointed and go through the air more easily. When they flap down, the wings straighten out, encounter more air resistance and generate more lift. (Maybe re-show the geese video).

Now let's talk about drag and thrust. When anything flies through the air, the air rubbing against it tries to slow it down. This is called drag. An airplane's engines, or in our case your hand, creates thrust and pushes an airplane forward. When an airplane is flying level and thrust is greater than drag, it speeds up. If there is less thrust than drag, it slows down. If thrust equals drag, we call that steady level flight (note that force is mass times acceleration, and while acceleration may be zero, velocity or speed is not necessarily so). Paper airplanes don't have engines, other than the initial push of your hand, so what keeps them from slowing down suddenly? It's like riding a bike down a hill: your airplane is coasting downward, and gravity pulls it forward.

Thrust/drag experiment: Everyone spread out and grab an unfolded sheet of paper again. With arms extended, clasp the paper between your palms, thumbs pointed up. Spin around, and while spinning remove your forward hand. It's drag that pushes the paper against your hand. If you stop spinning, you have removed thrust and the paper will drop to the ground.

Now let's fold one more airplane. The Delta was fast, the next one is not so fast – the Condor. It has different stability characteristics.

Paper Airplane #2. The Condor.

[Recommended time: 10 mins total]

Pass out the Condor templates and have the students fold their airplanes. Again, each group goes to a different part of the room (to their "runways") and students take turns flying their airplanes and discussing their successes and room for improvement based on the Paper Airplane Folding Video.

Discussion: What are the differences between the Delta and the Condor?

For Grade 5 and Older

[Recommended time: 15 mins]

Look at the wing shapes on the Delta and Condor. The distance from wingtip to wingtip is called wingspan, and they are quite different on these two planes. The Condor has a long wingspan, like a soaring bird, and the Delta has a shorter wingspan, like a dart. The distance from the front to the back of a wing is called the chord, and this is important, too. The ratio of wing span to average chord is called "aspect ratio," and is an important characteristic for wings.

Measure the wingspan and average chord (approximate average chord by measuring near the visual middle) of both the delta and the condor, calculating the aspect ratio, and comparing the results for the two planes.
For subsonic flight, or flight slower than the speed of sound, wing drag is reduced by increasing wingspan and decreasing chord, and thus increasing aspect ratio. Think of sailplanes – very long narrow wings. Airplanes that fly really fast – over 600 mph – have lowest drag with low aspect ratio swept back wings, so that's why jet fighters and the Concorde look the way they do. In the middle are jet airliners, which are sort of an in-between, and have high aspect ratio swept back wings.

Because paper is a terrible building material, all paper airplanes have pretty low aspect ratio wings. Still, we can get an idea of which airplanes fly better fast, and which fly better slow.

Wing shape experiment: Return to the group runways and try flying your Delta against your Condor, and see which flies better under what conditions.

More Advanced Lessons. (For Older Students)

[Recommended time: 10 minutes]

There is another paper airplane called the arrow. It's probably too difficult for most younger students, but fun for older students who might be developing a strong interest in paper airplanes or aerospace engineering. This plane has a much more sophisticated look than the basic Delta and Condor.

Let's think about why paper airplanes crash. Most are able to generate lift, so why don't they fly? The answer is that they become unstable. There are three main types of stability, pitch stability, roll stability, and yaw stability. (Show degrees of freedom & stability slide.)

First, let's discuss center of gravity. The center of gravity, or cg, is the point about which an airplane would balance and rotate if supported at a single point. If you place more weight at the nose, the cg shifts forward. If you place weight at the tail, the cg shifts aft.

Pitch stability: We need weight towards front of airplane to keep the nose from pitching too far up or down. That's because if an airplane receives an upward pitch disturbance and rotates around a point too far aft, too much wing surface forward will keep it rotating that way. But if the cg is forward, aft air striking the aft wing surface will push it back toward the original orientation.

Pitch stability experiment: The Arrow has plenty of weight (due to paper folds) at the front already, so is fairly stable and may even need a little "up-elevator." Up-elevator will raise the nose of the airplane and make it fly slower. Also, if needed, you could add a paper clip to shift the cg. Try adding elevator. Also, if you add too many paper clips too far aft, you can destabilize your airplane! Try it, and see.

Roll stability and dihedral: Make sure your plane has a slight "Y" shape to be stable. Try it with an inverted "V" shape. It will be less stable! Simple explanation: with a "Y," a roll disturbance will result in increased lift on the lower wing, causing the airplane to right itself. In a "V" configuration, the airplane keeps rolling.

Roll stability experiment

[Recommended time: 15 minutes]

Modify one of your planes, and try it both ways.

Yaw, or directional stability: Most airplanes have vertical stabilizers. Your Arrow has a vertical body. As long as the weight is forward, so that most of the rotating surface is to the rear, it will get pushed back in place under yaw disturbance.

Yaw experiment

[Recommended time: 5 minutes]

Try bending a little rudder into your airplane and see what happens.

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INTERNATIONAL PAPER

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RESOURCES

Videos about animals in flight
Turkey Vulture: https://www.youtube.com/watch?v=tJj2baRus0k
Geese: https://youtu.be/pdtpI33EXHQ
Hummingbirds: https://www.youtube.com/watch?v=Fouo6GKGBIM

Paper airplane folding tips by Ken Blackburn, the Guinness World record holder for paper airplane flight: https://www.youtube.com/watch?v=DwC3sTwCuds

LEARN MORE

Kids' Paper Airplane Book by Ken Blackburn & Jeff Lammers for explanations of aerodynamics, ideas for fun things to do, and more interesting templates. Ken Blackburn is the paper airplane Guiness World Record Holder for paper airplanes.

www.foldnfly.com for additional templates and corresponding folding videos.

The Great Paper Airplane Story (20 minutes)
https://www.youtube.com/watch?v=MKWqAiGaaz4

Flying with Vultures. (5 minutes. Recommended for largest screen you have - it's a beautiful video)
http://forum.hanggliding.org/viewtopic.php?t=19565

Amelia Earhart. (7.5 minutes)
#ameliaearhartforkids #ameliaearhartbiographyforkids #ameliaearhartvideo
https://www.youtube.com/watch?v=aI5n0sX8GE0

Charles Lindbergh. (6.5 minutes)
https://www.youtube.com/watch?v=68cjh5uDxFc

Video instructions for The Arrow (provided in downloads). This video supplements the written instructions, and could be helpful for older students or teachers, as The Arrow is an advanced paper airplane that may be difficult for some to fold.
https://www.youtube.com/watch?v=xykNOZL9_38

FORCES RELEVANT TO AIRPLANE FLIGHT