

NUMB3RS Activity: Experimenting with Paper Airplanes Episode: "Assassin"

Topic: Experimenting with Paper Airplanes

Grade Level: 9-12

Objective: Introduce the variables and mathematics of flight

Time: about 25 minutes

Materials: paper, yardstick, stopwatch, paperclips

Introduction

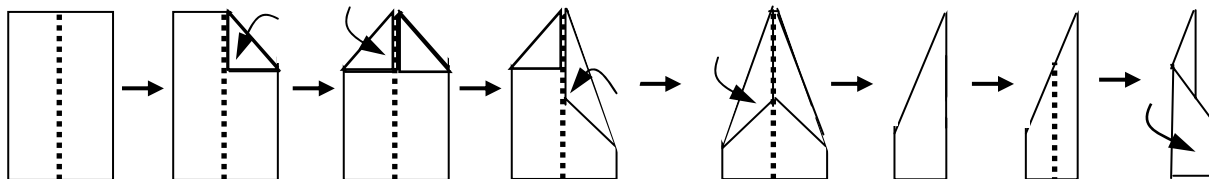
Aerodynamics, or the study of how objects move through the air, depends on a combination of math and physics. These concepts can be explored using a simple model airplane. The airplane's ability to move depends on four factors – drag, thrust, lift and gravity. Planes in flight have "drag", resistance to moving through the air. A plane's forward movement is thrust. Lift comes from the air below the wings and plane's in flight work against gravity's pull to the ground.

A paper airplane is basically a "flying wing". Constructing a paper airplane ignores many of the features of real airplanes such as wing flaps, a tail, and a sturdy body (fuselage), among others. The stability of an airplane depends on its center of gravity (its weight distribution). An unstable plane will pitch up or nose-dive, and will not fly far. Generally, a stable paper airplane has a heavy nose and positive lift from the wings. The more stable the plane, the farther it will fly.

Discuss with Students

In the episode "Assassin," Charlie and Larry discuss a paper airplane contest and some factors that affect the flight of a paper airplane. For example, the Reynolds Number measures how much the viscosity (thickness) of air affects a plane's flight. A high Reynolds Number means the plane is not as affected by the air's viscosity. Paper airplanes have low Reynolds Numbers. Because it is much simpler, a paper airplane can be easily modified and then tested to see how those changes affect its flight.

The first step is to make a simple paper airplane. Though there are many different types of paper airplanes, at first the same plane should be duplicated so that changes in it can be recorded. A simple plan for a paper airplane is shown below.



To test this paper airplane, make systematic changes to the final design and record how those changes affect its flight.

Student page answers: 1. Answers will vary with the adjustments made to the airplane.

2. $R = 3,904,248$; $L = 4800$; $V = 124$; $R = 7,799,526$; $L = 5400$. **3.** Direct proportion; k of 9346

4. The graph would be a line with slope 9346.

Name: _____ Date: _____

NUMB3RS Activity: Experimenting with Paper Airplanes

To perform a good experiment, you need to be able to *control* as many of the variables as possible. The variables in this experiment are factors that change from flight to flight. Thrust and angle of launch are two of these variables. *Thrust* is how much force the plane is thrown with and *angle of launch* is the angle that the plane makes with the ground when it is released.

Work in pairs. One person will throw the plane, and the other will record the measurements. Without altering the plane, experiment with thrust. See if throwing the plane softer or harder helps it fly further or stay in the air longer. Next, observe what happens when you alter the angle of launch. Adjust the angle of launch choosing low angles (< 45°) and higher ones (between 45° and 90°). To measure height, record where the plane is launched and use objects in the room as benchmarks for maximum height. To measure distance of flight, mark the floor where the nose is before the throw and then where it lands (do not measure sliding along the floor). Record your findings below.

Thrust	Angle of Launch	Distance of Flight (feet)	Maximum Height (feet)	Time in Air (seconds)
Hard	Low angle			
Soft	Low angle			
Hard	High angle			
Soft	High angle			

You can change the plane's center of gravity (the way the weight is distributed) by folding the nose in on itself to different lengths. This will make the plane shorter. You can also change the center of gravity by attaching paperclips to the nose of the plane, which will make the plane heavier. Make these adjustments and record your findings below. In this experiment, your thrust and angle of launch should remain as consistent as possible. Stability is measured by how much the plan wobbles, loops, or dives. A straight flight is considered "good".

Length of Plane (inches)	Number of Paperclips	Distance of Flight (feet)	Stability (good or bad)	Time in Air (seconds)

1. Pretend you are going to enter a paper airplane contest. Based on what you observed above, how would you design a plane to fly the farthest? How would you design a plane to stay in the air the longest? _____

Name: _____ Date: _____

The Reynolds Number for a plane measures how much a plane is affected by the thickness of air. In air, the Reynolds Number is calculated with the formula $R = K \cdot V \cdot L$, where K is the constant 9346, V is the velocity in miles per hour and L is the length over which the air is traveling (this is the width of the wing from front to back at about the middle of the wing). The Reynolds Number for a paper airplane is about 37,000 compared to that of a four-passenger airplane that has a Reynolds Number of about 6,000,000. The larger the number, the less the air affects the plane.

2. The table below compares the Reynolds Number of a paper airplane to several light airplanes at 75% of their cruising speed. Using your calculator, complete the table.

Type of Plane	K	V (mph)	L (width of wing) (feet)	Reynolds Number
Paper Airplane	9346	10	0.4	37,384
VP-2	9346	87	4.815	
Cessna 150	9346	108		4,833,562
Cherokee Cruiser	9346		4.857	5,615,547
RV-4	9346	175	4.780	

Data from <http://www.aerodrag.com/Articles/ReynoldsNumber.htm>

3. What type of proportion exists between the product of V and L and the Reynolds number? _____
4. If the Reynolds number were plotted against the product, VL , what would the plot look like? _____

The goal of this activity is to give your students a short and simple snapshot into a very extensive math topic. TI and NCTM encourage you and your students to learn more about this topic using the extensions provided below and through your own independent research.

Extensions

For the Student

- Try turning up the edges of the wings and see how this affects the flight of the plane.
- Try making your airplanes out of different materials (cardboard or heavier/lighter papers) and see how this affects the flight of the plane.
- Develop a method of finding the angle at which the plane is being thrown or the force with which it is thrown. How can you be sure the plane is being thrown at the same angle and with the same force each time? How does this uncertainty affect your conclusions?
- Further explore the data you collected by graphing the data with a scatter plot. For example, graph length of flight vs. number of paperclips. See if you can find a trend line and equation to fit the data.
- Using the data you gathered and graphs you've made, make hypotheses about how each variable affects the flight of the plane. Test your hypotheses by conducting more controlled experiments.
- Using what you've learned about paper airplanes, have a contest to see who can build one plane that will travel the furthest and one plane that will stay in the air the longest. Some guidelines to organizing a paper airplane contest can be found at <http://teacher.scholastic.com/paperairplane>

Resources:

<http://www.eecs.berkeley.edu/Programs/doublex/spring02/paperairplane>

A small website with the title "The Science of Paper Airplanes" with discussion of many of the topics broached in this activity; also includes links to related sites.

<http://www.grc.nasa.gov/WWW/K-12/airplane/bga.html>

NASA's Beginner's Guide to Aerodynamics, includes numerous links and discussions on a wide array of applications.

<http://www.paperplane.org>

Website of Ken Blackburn, the holder of world records in paper airplane flight; with slide show, experiments, and teacher's guide.

<http://education.ti.com/exchange>

Texas Instruments' free, collaborative forum where educators can share favorite activities using TI technology. Post an activity that has proven effective in your classroom or find a fresh way to teach a tough concept.