NATIONAL MUSEUM
OF THE UNITED STATES AIR FORCE™

SUMMARIZING DISTRIBUTIONS WITH PAPER AIRPLANE FLIGHTS

Students will make a paper airplane and use it to investigate flight distance and demonstrate an understanding of the forces of flight. The class will analyze and compare their data using line plots and bar graphs.

Grade Level: 5 – 8

Ohio Learning Standards/Science (2018)
Expectation of Learning
Nature of Science

Physical Science – Forces and Motion
5.PS.1: Change in movement of an object
8.PS.1: Force due to external field
8.PS.2: Forces can change motion

Ohio Learning Standards/Mathematics (2017)
Statistics and Probability
6.SP.4: Display numerical data
6.SP.5: Summarize numerical data sets

Statistical problem solving
7.SP.2: Broaden statistical reasoning
7.SP.3: Describe and analyze distributions

Materials Required:
- Pencils and markers
- Regular copy/printer paper
- Cellophane tape
- Low residue electrical-type tape for marking the floor
- Graph paper
- Measuring tape (preferred) or meter sticks
- Lined notebook paper
- Chart paper
- Sticky-back notes
- Model aircraft for demonstration purposes
- Pair of safety glasses for each student/adult
- Appendix A: Paper Dart design
- Appendix B: Paper Dart build instructions

LESSON PLAN

Lesson Objectives

Students will:
- Review the four forces of flight: lift, drag, thrust, and weight.
- Construct a paper dart airplane as directed.
- Measure the flight duration and length.
- Record and communicate data to create line plots and bar graphs.
- Apply and understand the math concepts of mode, mean, median and range.

Goal

In this lesson, students will apply the concept of the four forces of flight while also applying the math concepts of mode, mean, median and range.

Introduction/Background

The following is a brief background on the four forces of flight and control surfaces:

There are four forces working on an aircraft (including a paper airplane) in flight: lift, thrust, weight and drag.

- For an aircraft to fly, lift and thrust must be greater than weight and drag
- Airplane wings may have a special shape known as an airfoil. A common airfoil is nearly flat on its lower surface and curved on top
- Lift is explained through an understanding of Newton's First and Third Laws of Motion, the Bernoulli Principle and the Coanda Effect.
- Newton's First Law of Motion states that an object in motion stays in motion in a straight line unless acted upon by an outside force. Thus, there must be a force on the air to bend it down (the action).
- Newton's Third Law of Motion states that for every force there is an equal and opposite force: this force on the wing will then be up (the reaction).
- Bernoulli was a physicist and mathematician in the 1700s, and he discovered that when the speed of a fluid (including air) is increased, its pressure is decreased. The airfoil shape (and/or angle of attack) of the forward moving airplane's wing causes the air flowing over the curved top of the wing to move more quickly than the air

moving beneath the wing. This creates lower pressure above the wing and higher pressure under the wing, and the difference in air pressure causes the airplane's wing to rise (force).

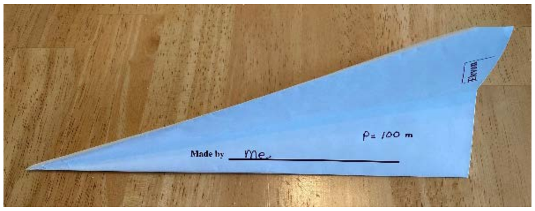
- To generate lift a wing must divert lots of air down! So how does the wing force the air down? The Coanda Effect: when a moving fluid, such as air or water, comes into contact with a curved surface it will try to follow that surface. This can be seen by holding a water glass horizontally under a faucet such that a small stream of water just touches the side of the glass. Instead of flowing straight down, the presence of the glass causes the water to wrap around the glass as you see in the next slide. Good video demonstration: https://www.youtube.com/watch?v=AvLwqRCbGKY
- This tendency of fluids to follow a curved surface is known as the Coanda effect. From Newton's first law we know that for the fluid to bend there must be a force acting on it. From Newton's third law we know that the fluid must put an equal and opposite force on the wing.
- The three control surfaces of an airplane are the ailerons, the elevator and the rudder.
  - The ailerons are traditionally located on the outer trailing edge of each wing and allow the pilot to control the airplane's movement along the longitudinal axis. This movement is referred to as roll.
  - The elevator is located along the rear edge of an airplane's horizontal stabilizer and allows the pilot to control the aircraft along the lateral axis. This movement is referred to as pitch.
  - The rudder is located on the rear portion of the vertical stabilizer and allows the pilot to control movement along the vertical axis. This movement is yaw.
- Aircraft with delta shaped wings (such as the Paper Dart airplane) have elevons, a combination of an elevator and an aileron. Used in conjunction, they act as an elevator. Used in opposition, they act as ailerons.

Safety concerns:

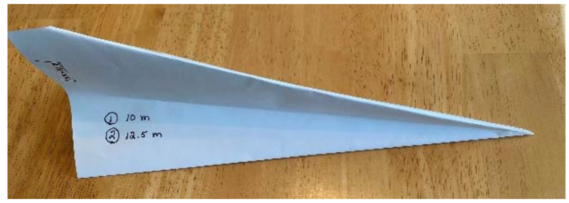
When flying the paper aircraft, students should wear protective safety glasses. In addition, ensure that no aircraft are flown directly at another person. Create a single direction fly zone: students should stand shoulder to shoulder in a straight line to throw the planes. All students in the line need to throw their aircraft at the same time and retrieve their aircraft at the same time. No one is to fly an airplane when students are retrieving airplanes.

Procedure:

1. Review with the students the four forces of flight and aircraft control surfaces. Draw a plane on chart paper and have the students draw arrows to represent the four forces and label the location of the major control surfaces. If this is new to the students, consider first completing the Lesson Plan "Principles of Flight" available on the National Museum of the USAF website.
2. Print a Paper Dart airplane on regular copy/print paper using Appendix A. Demonstrate and lead the construction of the paper dart airplane, following the instructions from Appendix B. Do not have the students fold or cut elevons at this time. Make sure the students put their names on the airplane.
3. Do the flying, if possible, in a gymnasium. Use tape to mark every 5 meters. All airplanes should be first thrown without any control surfaces engaged. Have the students first predict how far, in meters, their plane will travel. They should write their predictions on the plane (small writing to allow for other annotations) on the side with their name.
4. If available, use a SMART board to create a line plot. If not available, use a regular or magnetic white board. Or simply use large poster paper mounted on the wall. Have all students plot their predicted flight distances on the board. Use magnets or sticky notes. Be sure to have the students write their names on/by their predictions.
5. Next, carefully following the safety guidelines, allow the students to fly their planes in small groups, about 5 to 8 at a time. Do not retrieve airplanes until all groups have flown. Then the students should measure how far their airplane flew (using a measuring tape or meter stick and based on the guideline tape on the floor). Students should write down how far their plane traveled (measuring to the nose) on the side of the plane opposite from their name. Each flight should be numbered and all writing should be small to allow for multiple annotations.



Side with prediction annotated



Side with actual distances annotated

6. Next have the students add their actual flight distances to the line plot.

7. Discuss the class results: Whose plane flew the farthest? Whose plane flew the shortest distance? Who came closest to their prediction?

8. Using the line plot, review the concepts of mode, mean, median and range.

    a. What was the range? (shortest distance to longest distance)
    b. What was the mean? (add all distances and divide by number of students)
    c. What was the mode? (what distance was recorded most often – if any)
    d. What was the median? (the “middle” distance)

9. Using graph paper, have students create a bar graph showing the results for the entire class.

10. Have the students discuss why they think their plane flew well or didn’t fly well. How can they improve their planes? At this time, you may allow students to consider using the elevons. They may also build the same plane again with some improvements (not an entirely new design) – maybe improve building techniques, more accurate symmetry, use elevons, etc. The idea is to make improvements to the current design.

11. After the students make improvements to their planes, repeat the process above (steps 3 through 9).

12. Looking at the new class line plot and the updated answers to question number 8, ask the students why the improvements were/were not successful.

Evaluation/Assessment:

Students should be evaluated on participation, accuracy of calculations and ability to describe/observe/apply the four forces of flight.

Extensions:

1. Write a summary of the results of their paper airplanes' flight capabilities.
2. Calculate the average distance flown for the class as a whole and for the individual planes using a calculator.
3. Measure the time the planes are in flight using stopwatches and create line plots and bar graphs to show the results.
4. Compare and contrast their two planes in a short essay.

Resources:

Link to the Museum's principles of flight class

https://www.grc.nasa.gov/WWW/K-12/airplane/forces.html
https://www.hq.nasa.gov/office/aero/pdf/four_forces_5_8.pdf
https://www.nasa.gov/aeroresearch/resources/mib/four-forces-5-8
https://howthingsfly.si.edu/forces-flight
https://www.youtube.com/watch?v=AvLwqRCbGKY
https://study.com/academy/lesson/what-is-a-line-plot-in-math-definition-examples.html

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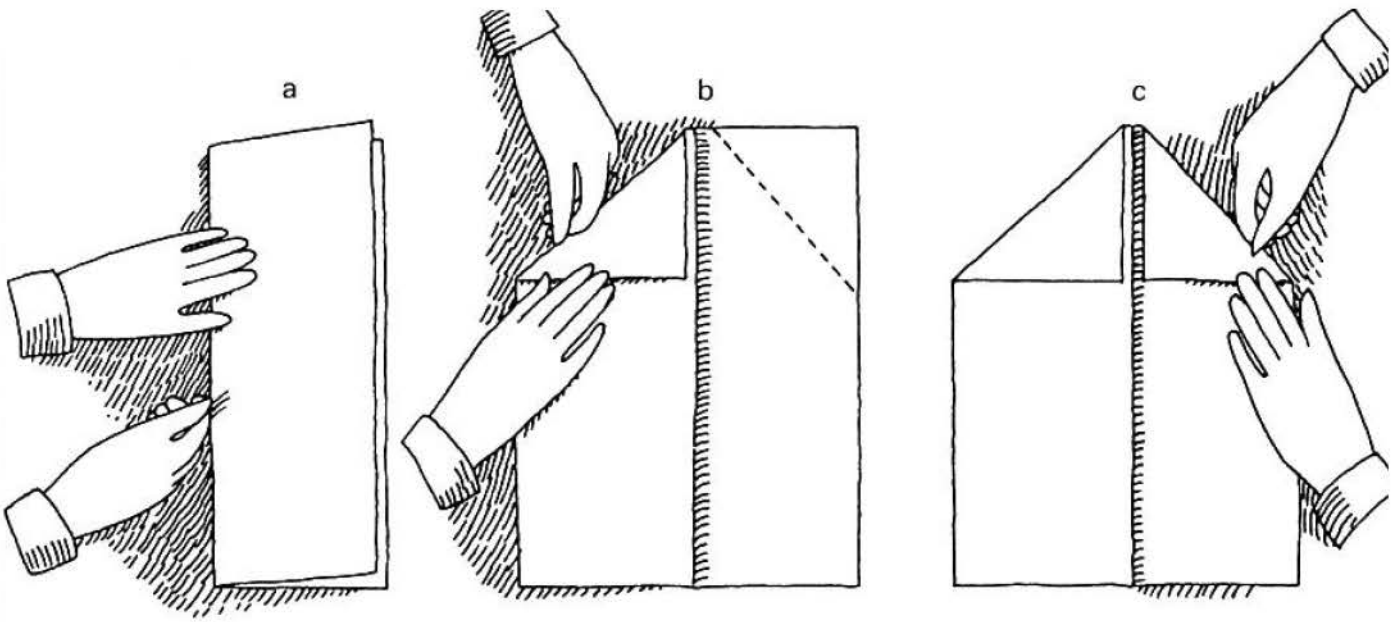
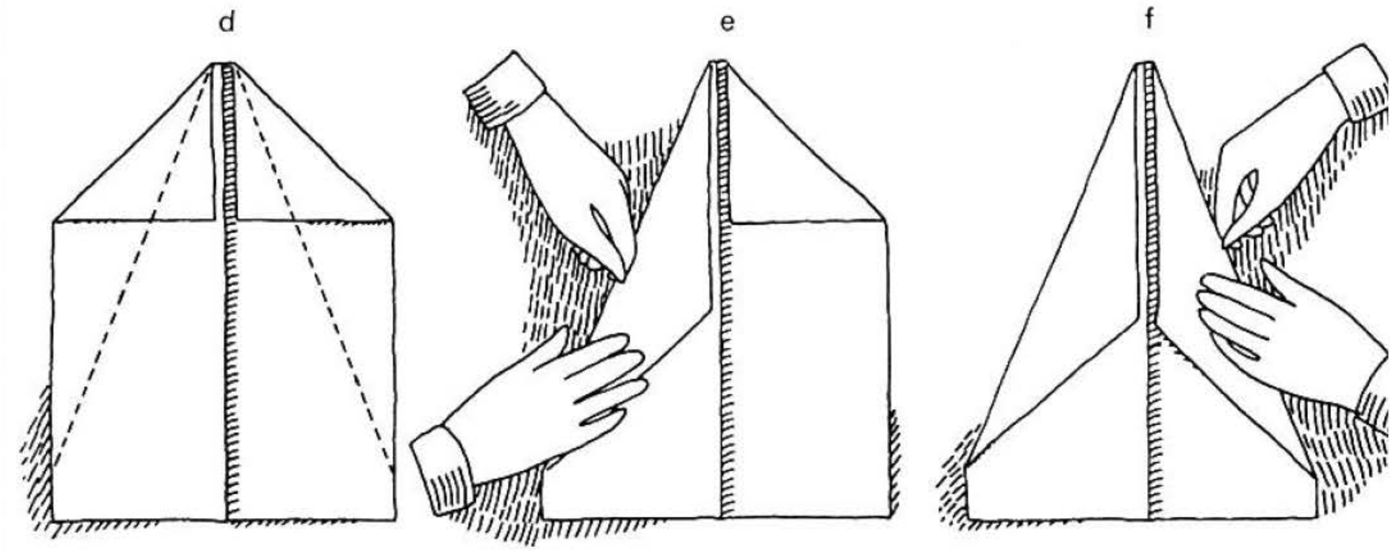
Let's make a paper airplane and see how these forces work in flight. Use a sheet of $8\frac{1}{2}$-by-11-inch paper.



Fold the paper in half lengthwise (a). Run your thumbnail along the fold to crease it sharply. Open the paper and fold one corner down toward the center (b). Fold the other corner down in the same way (c).



Fold one side again toward the center (e) along the dotted line shown in drawing d. Fold the other side (f) along the other dotted line. Make sure the folds are sharply creased.

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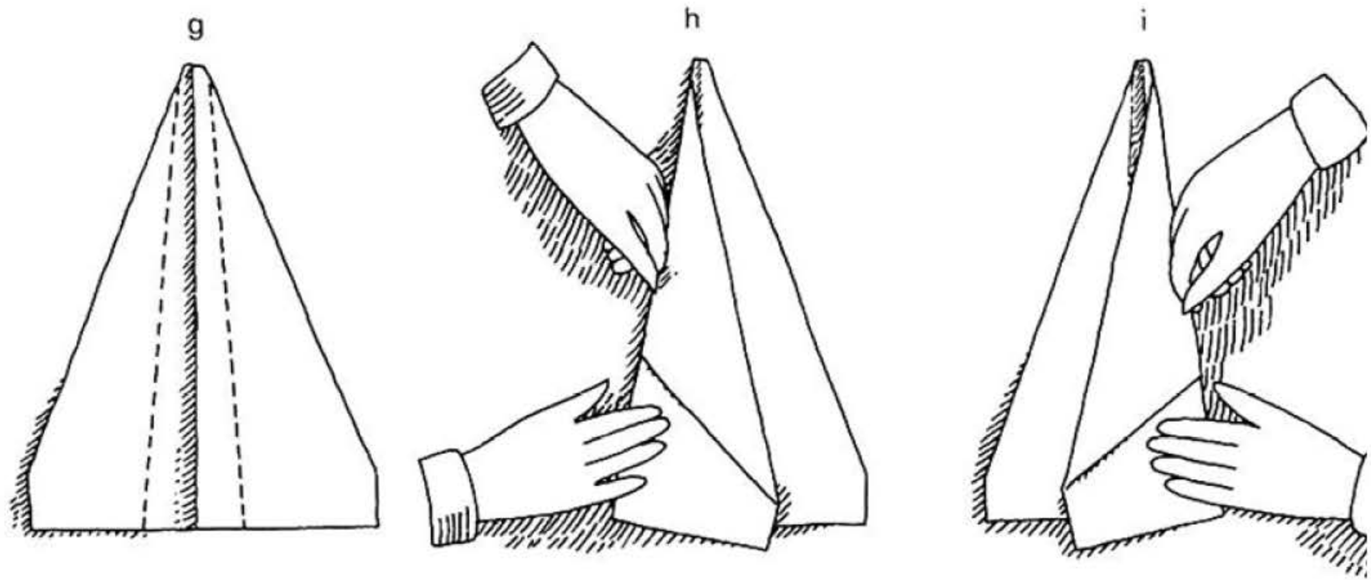
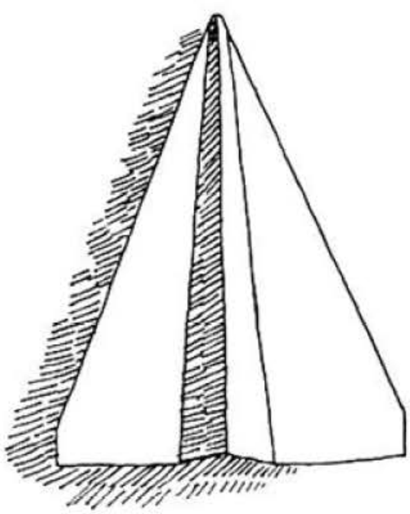
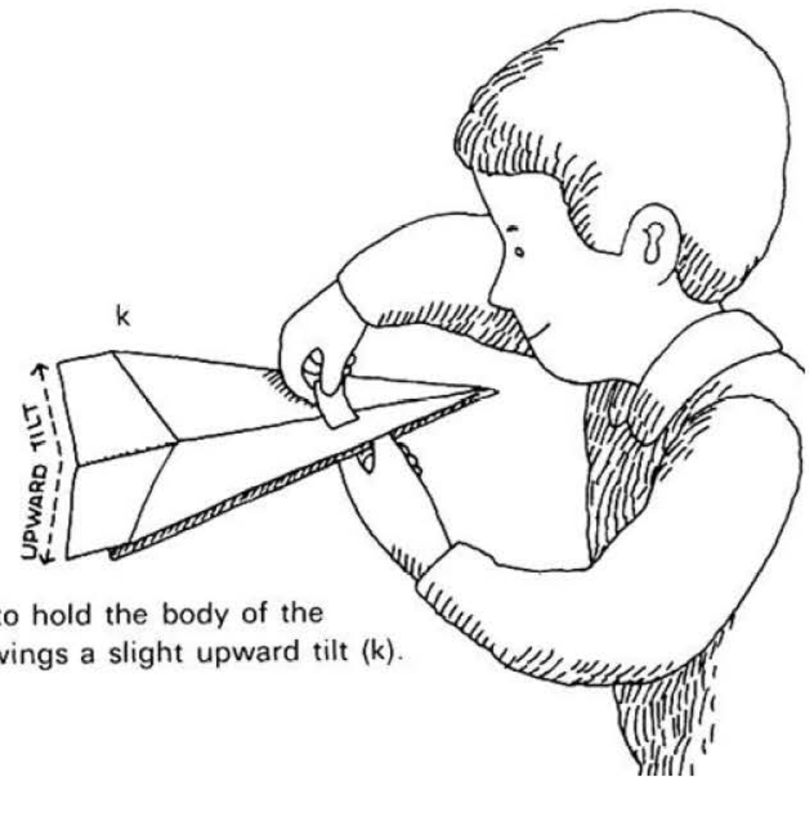


Turn the paper over. Fold one side over (h) along the left-hand dotted line shown in drawing g. Open the paper. Fold the other side over (i) along the right-hand dotted line in drawing g. From the bottom your plane should look like the one in drawing j.





Use a piece of cellophane tape to hold the body of the plane together and to give the wings a slight upward tilt (k).

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