

Paper Airplane Showdown and The Fundamentals of Flight

Lesson Plan for Grades 9-12

Length of Lesson: 2 hr 30 min (day 1 – Engagement through Explanation, day 2 – Explanation through Evaluation)

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Subject area/course: Physics and Aviation Science

Materials:

- Materials appropriate for making paper airplanes (cardstock, printer paper, scissors, glue, paperclips, etc...)
- Area for testing paper airplane flight
- Materials needed for experimental set up of flight experiments (ex. Rubber bands, meter sticks, measuring tape, 2x4's, etc....)

TEKS/SEs

- §112.39. Physics, Grade 9th-12th (2E, 2I)
- §112.39. Physics, Grade 9th-12th (4B, 4E)

Lesson objective(s): Students will be able to...

- design and implement investigative procedures, including making observations, asking well-defined questions, formulating testable hypotheses, identifying variables, selecting appropriate equipment and technology, and evaluating numerical answers for reasonableness
- identify and quantify causes and effects of uncertainties in measured data
- describe and analyze motion in one dimension using modeling with the concepts of displacement, velocity, and acceleration
- develop and interpret free-body force diagrams

Differentiation strategies to meet diverse learner needs:

- Search YouTube for videos of different languages similar to the linked videos, for ESL students
- Offer particular students private study projects if they have trouble collaborating with peers
- **(Advanced)** Offer particular students more challenging assignments such as researching the different types of wing positions and angles and how they affect flight stability and maneuverability (and justify these ideas with force diagrams and physics models).
- **(Advanced)** An additional follow-up challenge could be to have the same flight contest but have teams create their paper airplanes with the least number of folds possible.

ENGAGEMENT

- Teacher starts by first playing the “The ‘Wrong’ Brothers” video followed by the “Synergy Double Boxtail” video ([see resources section](#)).
- Teacher leads discussion about two videos by explaining how primitive aircraft evolved into sophisticated and even autonomous machines. “But what happened between those two videos? What realizations/discoveries were made that allowed for successful flight?”
- Teacher will show a diagram of a modern plane and explain the “plane anatomy.” ([see “Basic Aircraft Design explained” link in resources section](#)).
- Teacher will inform students that they will have a contest to design the best planes in terms of optimal flight

Paper Airplane Showdown and The Fundamentals of Flight

time. However, before the contest can begin the class must first decide on the ‘parameters for fair testing.’ In order to make valid tests, each plane must be tested under the same conditions and independently of the others, time recordings will help solidify actual competition results/standings. (Ex: class room gymnasium bleachers used for the testing setting. Paper airplanes could be launched from the same height and position in the bleachers using a meter stick and rubber band slingshot. The rubber band would be pulled the same distance back on the meter stick for each trial launch)

- Once the experimental design and contest parameters have been decided, students may proceed to create their planes

EXPLORATION

- Teacher can decide to allow students to work independently or in small groups.
- Students will be given paper airplane making materials ([see materials section](#)) to construct their initial models.
- Students will create detailed diagrams and instructions for building their paper airplane so that another person could accurately replicate the design.
- Students will then each test their models and record their max time aloft out of 3 independent tries.

EXPLANATION

- Teacher will breakdown the physics behind flight by addressing concepts such as lift, drag, propulsion force (thrust), force equilibrium, weight, and normal force.
- Teacher will reference a sample paper airplane design and draw a free body diagram which includes the plane’s estimated center of mass and all of the forces acting upon it during flight ([see “free body diagrams” link in resources section](#)).
- Teacher will lead a class discussion about the components of the paper airplanes and how each part contributes to the flight of the plane as a whole (i.e. wings help create lift, plane center body helps create balance, tip helps reduce drag, etc...) ([see “forces acting on paper airplanes” link in resources section](#)).

ELABORATION

- Students will make small adjustments to their initial models (creation of a secondary model) based on the new content delivered during the explanation section and document changes to their design/folding procedure.
- Students will then create 3 free body diagrams for their plane design centered on the plane’s estimated center of mass (1 for the plane during launch, 1 for the plane during midflight, 1 for the plane upon landing).
- Students will test their new design 3 more times and choose the data with optimal time aloft.
- Students will compare the data from the primary and secondary design to determine if the changes had a net positive or negative effect on the flight of the paper airplane.

EVALUATION

- Students will compare data with the class to determine which designs were ideal for optimal time aloft. Teacher will aid in discussion by asking questions such as “What about this plane design might have made it more ideal for having the largest time aloft of any plane in the class?”
- Exit Quiz:
 1. Draw the free body force diagram on a baseball that is thrown by a pitcher to the left.
 2. True or False: Wings on a plane create drag as well as lift.
 3. Were there any sources of error in the flight testing experiments? If so, what were some of them? Do you believe 3 tries were enough to determine how well your plane flew?

Paper Airplane Showdown and The Fundamentals of Flight

SOURCES AND RESOURCES

- Dr. Humphreys' Hot Science – Cool Talks Lecture #93: <http://www.esi.utexas.edu/hot-science-cool-talks/385-drones-myths-facts-hacks-and-the-future>
- The 'Wrong' Brothers Aviation Failures (1920's) video – https://www.youtube.com/watch?v=fw_C_sbfyx8
- Synergy Double Boxtail Aircraft Project video - <https://www.youtube.com/watch?v=GcDIXDRBJis>
- Basic Aircraft Design explained - <http://forum.kerbalspaceprogram.com/threads/52080-Basic-Aircraft-Design-Explained-Simply-With-Pictures>
- Fold n' Fly paper airplane designs - <http://www.foldnfly.com/#/1-1-1-1-1-1-1-2>
- Paper Airplane folding image source - <http://halo-angel.deviantart.com/art/Paper-Airplane-Tutorial-122098019>
- Free body diagrams - <http://www.mrwaynesclass.com/freebodies/reading/index01.html>
- Forces acting on paper airplanes - <http://paperaeroplanes.com/blog/?p=13>

Paper Airplane Showdown and The Fundamentals of Flight

EXPLORATION ACTIVITY or ACTIVITIES

Purpose:

In order to best understand the relationship between airplane design and function, students will participate in a paper airplane competition which is designed to create a craft that performs optimally in terms of time aloft (flight time). After the initial trial, students will receive more instruction and information on what variables affect flight and how physics modeling can help pinpoint the strengths and weaknesses of their airplane design.

Materials:

- Materials appropriate for making paper airplanes (cardstock, printer paper, scissors, glue, paperclips, etc...)
- Area for testing paper airplane flight
- Materials needed for experimental set up of flight experiments (ex. Rubber bands, meter sticks, measuring tape, 2x4's, etc....)

Safety Information:

Students follow common safety materials protocol (i.e. scissor safety, etc...).

Teachers should select a testing ground that is suitable for experimentation yet safe and controllable. Teachers should ask for additional help from fellow staff members if needed.

Potential hazards are present if students are working at an elevated height (i.e. roof top or from a ledge/balcony).

Procedure:

(EXPLORATION):

- Teacher can decide to allow students to work independently or in small groups.
- Students will be given paper airplane making materials ([see materials section](#)) to construct their initial models.
- Students will create detailed diagrams and instructions to building their paper airplane so that another person could accurately replicate the design.
- Students will then each test their models and record their max time aloft out of 3 independent tries.

(ELABORATION):

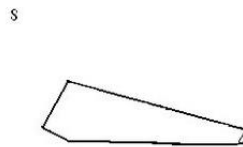
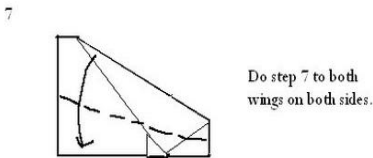
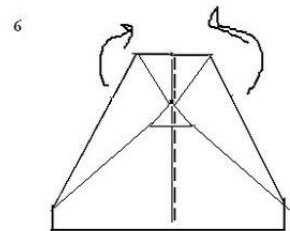
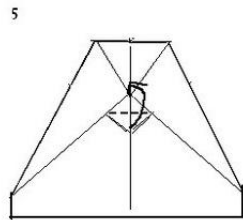
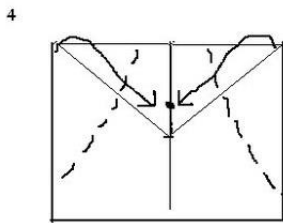
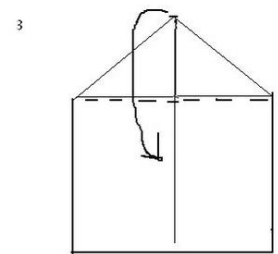
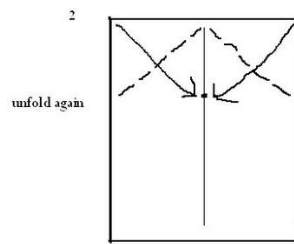
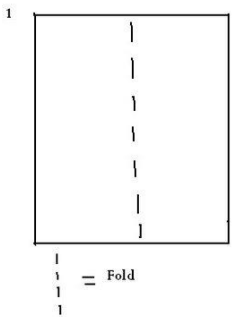
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Paper Airplane Showdown and The Fundamentals of Flight

TEACHER PAGE(S)

Exploration:

You and your partner/group will be provided materials necessary for the creation of a paper airplane. Your goal is to design an airplane that performs well in terms of time aloft (amount of time in the air). Initial plane designs may be based on past experience or on examples of real aircraft. Document your building process below by sketching each folding step and by using notes and arrows when necessary. Your instructions should be specific enough so that a perfect stranger could build your paper airplane.



Now simply elevate the wings and you are done! -Be sure to make the wings angles slightly upwards then just straight at a 90 degree angle. It'll fly better. ;)

Paper Airplane Showdown and The Fundamentals of Flight

Now, you and your partner/group will test your plane according to the experimental parameters that you and your class decided upon earlier. Record your three trials below.

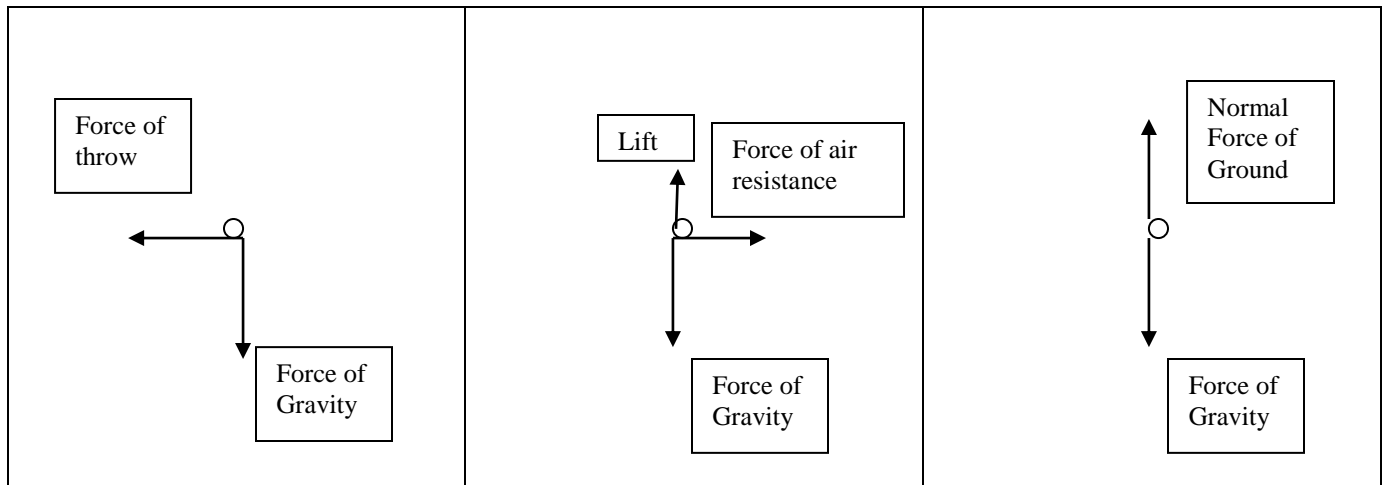
	Trial 1	Trial 2	Trial 3
Time Aloft (seconds)	10	2	5

Elaboration:

Now that you have received further instruction and learned more about what affects flight, make some modifications to your airplane and document them below in a similar fashion to what was done previously.

Paper Airplane Showdown and The Fundamentals of Flight

Create 3 free body diagrams for their plane design centered on the plane’s estimated center of mass (1 for the plane during launch, 1 for the plane during midflight, 1 for the plane upon landing).



Test your new design again and record your new data below

	Trial 4	Trial 5	Trial 6
Time Aloft (seconds)	10	8	8

Did your design improve your time aloft? How do you think your design influenced the positive or negative change that you saw with the second experiment?

There were positive improvements in both the time aloft. This was probably because we added flaps to the rear portion of the wings and made the surface area of the wings larger than before.

Paper Airplane Showdown and The Fundamentals of Flight

Name: _____

Date: __/__/____

Name: _____

Date: __/__/____

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