

**Lesson Title:** Flight Forces

**Topic:** Contact and Noncontact Forces, Force and Motion

**Targeted Grade Level:** 8<sup>th</sup> Grade Physical Science

**Student Population:** This lesson will be taught to approximately eighty 8<sup>th</sup> grade physical science students at a small middle school in central Pennsylvania. The majority of the student population, 87%, is white, 7% are Hispanic, 2% are black, and 3% are two or more races. Over half of the student population, 54%, receives free or reduced-price lunches.

**Time Needed:** 2 Block Periods

1<sup>st</sup> Block: Engage, Explore, Explain

2<sup>nd</sup> Block: Elaborate, Evaluate

**Level of Inquiry:** Inquiry Lesson

According to Wenning (2015), this is an inquiry lesson because the students learn through the “process of scientific experimentation” by “observing and listening, and responding to questions” (p. 5). In this particular lesson, the students will complete four activities to discover the four forces acting on a plane in flight and determine how the forces affect the plane’s motion.

**Standards:**

*PA Science Assessment Anchors, and Eligible Content:*

S8.C.3.1 Describe the effect of multiple forces on the movement, speed, or direction of an object.

- S8.C.3.1.1 Describe forces acting on objects (e.g., friction, gravity, balanced versus unbalanced).

S8.A.2.1 Apply knowledge of scientific investigation or technological design in different contexts to make inferences to solve problems.

- S8.A.2.1.1 Use evidence, observations, or a variety of scales (e.g., mass, distance, volume, temperature) to describe relationships.
- S8.A.2.1.5 Use evidence from investigations to clearly communicate and support conclusions.

***NOTE:*** Pennsylvania has not yet adopted the Next Generation Science Standards. The state is currently reviewing the standards to better align with NGSS.

NGSS Performance Expectations:

**MS-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.**

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
<p><b>Constructing Explanations and Designing Solutions</b>            Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.</p> <ul style="list-style-type: none"> <li>Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. (MS-PS3-3)</li> </ul>	<p><b>PS2.A: Forces and Motion</b></p> <ul style="list-style-type: none"> <li>The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)</li> <li>All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MSPS2-2)</li> </ul> <p><b>PS2.B: Types of Interactions</b></p> <ul style="list-style-type: none"> <li>Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)</li> </ul> <p><b>ETS1.B: Developing Possible Solutions</b></p> <ul style="list-style-type: none"> <li>A solution needs to be tested, and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. (<i>secondary to MS-PS3-3</i>)</li> </ul>	<p><b>Cause and Effect</b></p> <ul style="list-style-type: none"> <li>Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-3),(MS-PS2-5)</li> </ul> <p><b>Systems and System Models</b></p> <ul style="list-style-type: none"> <li>Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems. (MS-PS3-2)</li> </ul> <p><b>Stability and Change</b></p> <ul style="list-style-type: none"> <li>Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales. (MS-PS2-2)</li> </ul> <p><b>Influence of Science, Engineering, and Technology on Society and the Natural World</b></p> <ul style="list-style-type: none"> <li>The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-PS2-1)</li> </ul>

### **Measurable Student Learning Objectives:**

Students will be able to...

- Identify the contact and noncontact forces acting on a plane.
- Explain how flight forces influence the motion of a plane.
- Design and build an efficient model airplane using knowledge of the four flight forces.

### **Differentiation of Instruction:**

Learning support students:

- Have text read aloud, upon request
- Have 3 (as opposed to 4) answer choices on final assessment
- Administer assessments in small group setting
- Offer extended time, as needed
- Any other modifications as directed by individual IEP

ELL Students:

- Offer extended time, as needed
- Abbreviated assignments
- Have text read aloud upon request
- Repeat/Post instructions
- Guided Notes

GIEP Students:

- Adaptations and modifications will be made based upon students specially designed instruction (SDI) documents, district provided data, GIEP goals, and/or recommendations from the GIEP Team.

\*Specific adjustments included in the lesson procedure.

### **Possible Misconceptions:**

- Students think that you can see forces.
- Students believe objects must touch to exert force.
- Students do not realize that objects have forces acting upon them at rest and while in motion.

## Lesson Procedure:

5E Model	5E Objectives
<p><b><u>Engage</u></b> Students watch an engaging video on stunt planes and generate questions about airplanes in flight.</p>	<p><b>Procedure:</b></p> <ol style="list-style-type: none"><li>1. Show students the <a href="#">Stunt Planes YouTube Video</a>. Advise them to pay close attention to the structure and motion of the planes.</li><li>2. Video reflection: Students reflect on the video in their science notebook generating a list of questions that come to mind about airplanes after viewing the stunt routines. Possible student questions:<ol style="list-style-type: none"><li>a. How are the pilots able to stay in the airplanes when upside down or doing flips?</li><li>b. How do large airplanes stay up in the air without falling?</li><li>c. What is coming out of the back of the planes as they fly?</li><li>d. Why do some planes have four wings, while others only have two?</li></ol></li><li>3. Class discussion: Utilize think-pair-share and random name generator to ensure participation<ol style="list-style-type: none"><li>a. What was the same/different about planes?</li><li>b. Describe the motion of the planes.</li><li>c. What are some things that engineers have to think about when designing and building an airplane?</li></ol></li><li>4. Express that the investigation students are going to complete in class today will help answer some of their questions and help them understand the flight of planes.</li></ol> <p><b>Modifications:</b></p> <ul style="list-style-type: none"><li>• Have discussion questions posted for struggling learners and ELL students</li><li>• Brainstorm a list of video reflection questions as a class if students are stuck</li></ul> <p><b>Formative/Summative Assessments:</b></p> <ul style="list-style-type: none"><li>• Discussion Questions (formative)</li></ul>

	<p><b>Resources:</b></p> <ul style="list-style-type: none"> <li>• Engagement video: <a href="#">Stunt Planes YouTube Video</a></li> <li>• Science Notebook</li> </ul>
<p><b><u>Explore</u></b> Students complete an inquiry activity to experience, observe, and discover the forces acting on a plane.</p>	<p><b>Procedure:</b> <i>Prior to lesson, set up four stations according to the “Understanding the Forces” activity in the <a href="#">NASA Principles of Flight: Four Forces</a> guide (p. 8 – 10).</i></p> <ol style="list-style-type: none"> <li>1. Students work in small groups and rotate to four stations to complete an inquiry activity called “Understanding the Forces”. Each group performs the activities described at each station. The stations demonstrate the four forces of flight:       <ol style="list-style-type: none"> <li>a. Station 1: Thrust</li> <li>b. Station 2: Drag</li> <li>c. Station 3: Weight</li> <li>d. Station 4: Lift</li> </ol> </li> <li>2. For each station, students follow the directions on the Understanding the Forces Worksheet (attached) to complete the activities and record their data and observations.</li> <li>3. After completing the four stations, students complete the conclusion questions of the inquiry activity.</li> </ol> <p><b>Modifications:</b></p> <ul style="list-style-type: none"> <li>• Read station directions aloud</li> <li>• Modify Understanding the Forces Worksheet with data tables for struggling learners and ELL students</li> </ul> <p><b>Formative/Summative Assessments:</b></p> <ul style="list-style-type: none"> <li>• Understanding the Forces Worksheet- Conclusion questions (formative)</li> </ul> <p><b>Resources:</b></p> <ul style="list-style-type: none"> <li>• <a href="#">NASA Principles of Flight: Four Forces</a> guide</li> <li>• Understanding the Forces Inquiry Activity Materials:</li> </ul>

	<ul style="list-style-type: none"> <li>○ Balloons (one per student)</li> <li>○ Stopwatches</li> <li>○ 2 small balls (similar size, different mass)</li> <li>○ Fan</li> <li>○ Umbrella</li> <li>○ Scale</li> <li>○ Balloon Pump</li> <li>○ Copy Paper</li> <li>● Understanding the Forces Worksheet (attached) (one per student)</li> </ul>
<p><b><u>Explain</u></b> Students read an article and watch a video to understand the four forces of flight.</p>	<p><b>Procedure:</b></p> <ol style="list-style-type: none"> <li>1. Explain that each of the stations students experienced represented a force acting on a plane during flight. Each of the forces has a special name. Address misconceptions with a brief class discussion:       <ol style="list-style-type: none"> <li>a. Were you able to see the forces at each station?</li> <li>b. When did the objects have forces acting upon them?</li> <li>c. Were all of the forces exerted through contact?</li> </ol> </li> <li>2. Students read “The Forces of Flight” passage in the <a href="#">NASA Principles of Flight: Four Forces</a> guide (p. 3 – 7) to learn the four terms to identify the forces that they experienced in the inquiry lab.</li> <li>3. Students watch <a href="#">NASA’s Get it Wright Podcast/Video: “The Four Forces of Flight”</a> to learn how the forces of flight influence airplane design.</li> <li>4. Students independently complete the <a href="#">Forces of Flight Quizizz</a> to assess their understanding of thrust, drag, weight, and lift.</li> <li>5. Students must finish any tasks for homework if incomplete by the end of class.</li> </ol> <p><b>Modifications:</b></p> <ul style="list-style-type: none"> <li>● Audio recording of “The Forces of Flight” passage available</li> </ul> <p><b>Formative/Summative Assessments:</b></p> <ul style="list-style-type: none"> <li>● Forces of Flight Quizizz (formative)</li> </ul> <p><b>Resources:</b></p>

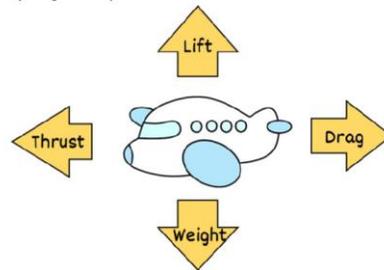
- [NASA Principles of Flight: Four Forces](#) guide “The Forces of Flight” passage
- [NASA’s Get it Wright Podcast/Video: “The Four Forces of Flight”](#)
- [Forces of Flight Quizizz](#)
- Student devices (laptops) with internet access

**Procedure:**

1. Review the four forces of flight students explored, discovered, and learned about yesterday in the inquiry activity. Use the image, descriptions, and questions below as a quick review.

**The four forces of flight:**

Lift, drag, weight and thrust are the forces acting on an airplane. To maintain a steady flight requires balance of all the four forces.



**Thrust:** It is the force that moves a flying machine in the direction of motion. It is created with a propeller, jet engine or rocket. Paper airplane gets its thrust from the person throwing it. So, to increase thrust, you'll need to throw it harder!

**Drag:** It is the force that acts opposite to the direction of motion. It tends to slow down an object. Drag is caused by friction or differences in air pressure. The front of an airplane is narrow to create less drag. The shape of the airplanes are designed in such a manner that it moves easily through the air.

**Lift:** It is the force that holds an airplane in the air. The wings create most of the lift used by airplane. As air travels around an airplane wing, it moves faster over the top and slower under the bottom. This creates low pressure above the wing and high pressure under the wing. This high pressure acts as a lifting force allowing the airplane to fly.

**Weight:** It is the force caused by gravity. It acts in downward direction towards the earth. The amount of gravitational pull is equal to how heavy or light the object is. To fly, the force of weight must be less than the force of lift. Paper airplanes that weighs less will fly farther so it must be made with a lighter paper.

- a. Why do things fly?
  - b. Why do planes move forward?
  - c. Why do planes glide in the air?
  - d. Why do planes stop after its flight and glides down?
  - e. What are the forces acting on a plane?
2. Introduce the Paper Airplane Challenge (attached) to the students. Review the steps of the Engineering Design Process, available materials, and timeline of the challenge.
  3. Brainstorm: 5 minutes

**Elaborate**

Students complete an engineering challenge to design an efficient model airplane using knowledge of the four flight forces.

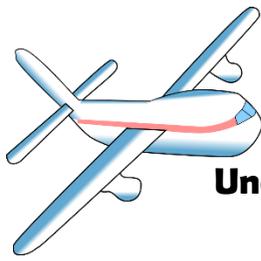
- a. Students research successful paper airplane design models.
- b. Questions to guide brainstorming:
  - What are different about previous paper airplane designs?
  - What are the strengths and weaknesses of each design?
  - Which idea is most useful?
4. Design: 5 minutes
  - a. Students sketch a few possible design options, weigh the pros and cons of each design, and select a design to build.
5. Build: 10-15 minutes
  - a. Students gather necessary materials to build their paper airplane.
6. Test & Evaluate: 20 minutes
  - a. Have students make a prediction on how far their plane will fly.
  - b. Take students outside to test their design.
  - c. Students throw their plane and measure the distance it flies.
  - d. Students must complete at least three trial for their airplane and reflect on the design's strengths and weaknesses.
7. Redesign: 10 minutes
  - a. Students design and rebuild a paper airplane.
8. Test & Evaluate: 10-15 minutes
  - a. Take students outside again to test their second design.
  - b. Students complete at least three trials of testing.
9. Solution and Self-Reflection 10-15 minutes
  - a. Students reflect on their designs and data collected to determine the best design for a paper airplane.
  - b. Have the students share their final solutions with the class.
  - c. As a class, determine the forces acting on the paper airplanes and the properties of efficient paper airplanes that fly the farthest.

**Modifications:**

- Have discussion questions posted for struggling learners and ELL students
- Provide resources for students to research paper airplane designs

	<ul style="list-style-type: none"> <li>• Use questioning to help students brainstorm and design if they become stuck</li> <li>• Guided set-up of data collection table together as a class for struggling students</li> </ul> <p><b>Formative/Summative Assessments:</b></p> <ul style="list-style-type: none"> <li>• Paper Airplane Challenge (summative)</li> </ul> <p><b>Resources:</b></p> <ul style="list-style-type: none"> <li>• Paper Airplane Challenge (attached) (one per student)</li> <li>• Paper Airplane Challenge Materials: <ul style="list-style-type: none"> <li>○ Tissue paper</li> <li>○ Copy Paper</li> <li>○ Newspaper</li> <li>○ Scissors</li> <li>○ Tape</li> <li>○ Rulers</li> <li>○ Meter stick</li> </ul> </li> </ul>
<p><b><u>Evaluate</u></b>  Students use their knowledge of kinetic and potential energy to design and build a successful rollercoaster of their own and calculate the kinetic and potential energy of the marble as it completes the rollercoaster track.</p>	<p><b>Procedure:</b></p> <ol style="list-style-type: none"> <li>1. Students independently complete the Forces of Flight Exit Ticket (attached) to assess their understanding of thrust, drag, weight, and lift and how these forces influence the motion of a plane.</li> </ol> <p><b>Modifications:</b></p> <ul style="list-style-type: none"> <li>• Chunk the Exit Ticket prompt into separate questions</li> </ul> <p><b>Formative/Summative Assessments:</b></p> <ul style="list-style-type: none"> <li>• Forces of Flight Exit Ticket (summative)</li> </ul> <p><b>Resources:</b></p> <ul style="list-style-type: none"> <li>• Forces of Flight Exit Ticket (attached) (one per student)</li> </ul>





## Understanding the Forces

### Station 1:

1. Inflate a balloon using four breaths or four pumps of a balloon pump.
2. Let go of the balloon.
3. Time how long the balloon flies.
4. Repeat multiple times with various levels of inflation, recording the number of breaths and flight time for each trial.

Record observations and data:

### Station 2:

1. Student 1 runs from point A to point B.
2. Time the student's journey.
3. Student 1 runs from point A to point B again, but this time holding an open umbrella.
4. Time the student's journey.
5. All students in the group must complete the runs.

Record observations and data:

### Station 3:

1. Make observations about the two balls at the station.
2. Stand on the chair and hold the balls at arm's length at equal height.
3. Predict which ball would fall to the ground first.
4. Drop the balls simultaneously and observe.
5. Take two sheets of paper. Crumple one into a ball.
6. Stand on the chair and hold the papers at arm's length at equal height.
7. Hypothesize which paper will fall to the ground first.
8. Drop the papers simultaneously and observe.

Record observations and data:

**Station 4:**

1. Hold one hand flat against the blowing stream of air from the fan.
2. Tilt your hand upwards slightly.
3. Hold you tilted hand against the fan and observe.

Record observations and data:

**Conclusion Questions**

1. Station 1: What correlation was there between the amount of air in the balloon and its flight time?

2. Station 2: Why was it significantly harder to run with the open umbrella? Why were the sprinting times longer with the umbrella than without?

3. Station 3: Why did both balls fall to the floor at approximately the same time even though one was heavier?

4. Station 4: Explain what happens when your hand was turned upwards. Why?

# Paper Airplane Challenge



**Challenge:** Design and build a paper airplane that can fly as far as possible.

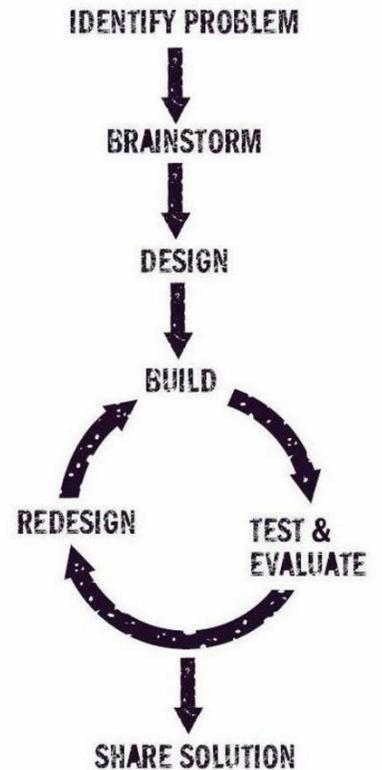
**Materials:**

- Tissue Paper
- Copy Paper
- Newspaper
- Scissors
- Tape
- Ruler
- Meter Stick (for testing designs)

**Identify the Problem:** Questions to ponder.

1. What is the goal of the challenge?
  
  
  
  
  
  
  
  
  
  
2. What are some constraints the engineers would have to consider when designing an airplane?

## THE DESIGN PROCESS



**Brainstorm:** Conduct some research on prior designs.

Record observations of prior designs.

**Design:** Sketch multiple options and decide which design to build.

Remember to label all parts of the sketches.

Teacher Check: \_\_\_\_\_

**Build: Create it!**

**Test & Evaluate:** Collect data and reflect to evaluate the design.

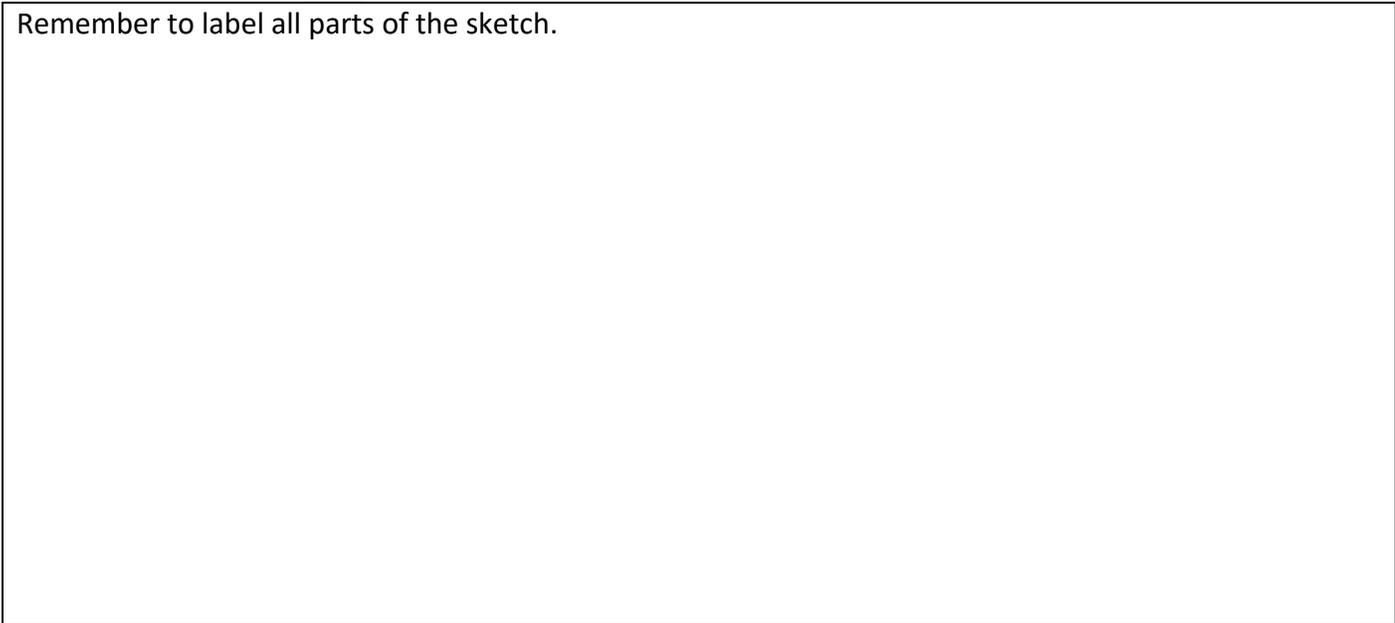
	Data Collection Test at least three trials for each design.	What is Working?	What Needs to be Improved?
Design 1			

<b>Design 2</b>			
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**Rebuild, Test & Evaluate:** Collect data in the table above.

**Solution:** Sketch you final design and explain why this is the best design.

Remember to label all parts of the sketch.



**Self-Reflection:**

1. What did you learn from this experience? Would you want to do this again?
  
2. What were some creative risks that you took?
  
3. Why is it important to brainstorm with others?

# FORCES OF FLIGHT

## EXIT TICKET

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