

## *Jets in Flight*

*Science Topic: Physics*

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**Grades:** 9<sup>th</sup> – 12<sup>th</sup>

### **Essential Questions:**

- How is it possible for a vehicle that weighs 20,000 pounds to fly?
- What conditions are needed to make this plane take flight on a runway that is 87% smaller than the necessary runway length?
- How can we simulate these conditions using conceptual models?

### **Lesson Overview:**

Students will create physical and conceptual models for planes in flight designed according to the engineering design process.

**A companion interactive resource that incorporates video and glossary terms used throughout this lesson is provided to use in classroom.**

### **Learning Objectives:**

#### *Evaluation*

- Interpret data related to motion and flight
- Select an optimal design from among alternatives to solve a technological problem

#### *Synthesis*

- Explain the principles of flight in mathematical and physical terms
- Integrate mathematics and physics in the engineering design process

#### *Analysis*

- Analyze the physical principles of lift and propulsion and relate these to aircraft construction
- Use mathematics to calculate lift and flight speed

#### *Application*

- Use the engineering design process to construct an aircraft prototype

#### *Comprehension*

- Define constraints to the construction of a proposed model
- Explain how solutions to a problem address the specific requirements

### *Knowledge*

- Explain the relationships of the principles of motion to the concepts of lift, drag and thrust
- Describe the engineering design process
- Demonstrate how a prototype addresses the requirements of lift and propulsion

## **National Science Education Standards**

### **Science as Inquiry**

Students will

- Identify questions and concepts that guide scientific investigations
- Design and conduct scientific investigations
- Use technology and mathematics to improve investigations and communications
- Formulate and revise scientific explanations and models using logic and evidence
- Communicate and defend a scientific argument

### **Physical Science**

- Use mathematics and logic to explain scientific principles

### **Science and Technology**

- Identify a problem or design an opportunity
- Propose designs and choose between alternative solutions
- Implement a proposed solution
- Evaluate a solution and its consequences
- Communicate the problem, process, and solution

### **Time Frame:**

This lesson is designed to be completed in two 90-minute sessions.

### **Vocabulary:**

- *Propulsion*: Provides a force against the expelled gases or wind such that its counter force pushes the plane forward.
- *Catapult*: Launches the plane from the carrier
- *Thrust*: The force that gives the plane propulsion and overcomes drag
- *Lift*: Upward force acting in the opposite direction of weight
- *Drag*: Air friction or the resistance force acting on the plane

### **Background for the Teacher:**

In this lesson, students will examine principles and processes of science and engineering to understand how aircraft fly. The instructor will use the PowerPoint slideshow *Designing a Navy Jet Fighter* to facilitate instruction, discussion, and demonstration. The unit is divided into two parts. In Part 1, students will learn the basic physical principles involved in flight. They will study the opposing forces that affect an airplane's motion and capability to fly.

In Part 2 the students will design a prototype aircraft and launching system to simulate the conditions of launch from an aircraft carrier and sustained flight. Working in groups they will use the

Engineering Design Process to develop their models. Finally, students will demonstrate their prototypes and explain their project's evolution through the Engineering Design Process.

## **Engage**

*(PowerPoint Slides 1-5)*

Have students work in small groups. Ask them to discuss this question:  
How do airplanes stay in flight? Create a mind map of their current understanding of flight.

Introduce the video #1.

Students should pay attention to the plane at launching as well as leaving the platform.

As a class discussion, ask these questions:

- What is the purpose of a catapult?
- Why must a plane use thrusters (with heat shield) and be held in place before being released?
- Why is the takeoff strip slightly angled upwards?
- Normally most of these planes need a 3,000 foot runway for takeoff, so how are they able to takeoff from a 300 foot airstrip?

Explain that all of these parts (catapult, heat shield, held-back thrusters) are all used to help the plane gain enough velocity to build lift for liftoff.

Ask the students to discuss the relationship between velocity and lift.

Explain to students that they will work to answer these questions during the lesson:

- a. How is it possible for a vehicle that weighs 20,000 pounds to fly?
- b. What conditions are needed to make this plane take flight?

## **PART 1**

### **Explore**

*(PowerPoint Slides 6-8)*

These slides will gauge students' background and give them an opportunity to share their understanding of the parts of an airplane. Three NASA graphics depict a generic aircraft with connector lines and labels indicating the functioning parts. Break students into groups to see which group can identify the most parts on slide 6. If students struggle, allow them to use text or web resources to locate the parts and their function.

As a class discussion, ask these questions:  
What parts of an airplane are vital to flight?

Explain that the parts indicated on slide 8 are the only mechanisms needed for straight and leveled flight. These are the:

- Wing
- Engine
- Fuselage
- Vertical stabilizer
- Horizontal stabilizer

### **Explain**

*(PowerPoint Slides 9-17)*

In this segment of the lesson, students will learn about the basic physics of flight. Thrust and lift may be new concepts for most of the students. Lift is described in terms of Bernoulli's principle. You may wish to challenge students' understanding by asking if a plane is *pushed* upward or *pulled* upward. Be sure to emphasize that flight and propulsion are achieved by shifting the balance between the four opposing forces thrust, lift, weight, and drag.

Weight and Drag are working against the airplane. Gravity is pushing down on the plane, and drag is working to slow the plane down. In order for the plane to lift-off thrust and lift must be used to counteract these forces.

Thrust is produced in one of two ways:

- Transfer of momentum when gases are ejected to the rear of the plane through jet engines.
- Launching a plane with a catapult from the deck of an aircraft carrier.

Lift is the upward force created as air passes over and beneath the wings of an aircraft. Bernoulli's Principle explains the phenomenon of lift.

- Fast moving air at the top edge of the wing creates a zone of low pressure.
- Slow moving air along the bottom edge of the wing has the same pressure as the air at the front of the wing (Ambient Pressure).
- The difference in pressure creates the force of lift.
- Additional upward force is generated incoming air deflects off the bottom of the wing and transfers momentum to the wing

To simulate Bernoulli's Principle utilize the flow simulation at this NASA website

<http://www.grc.nasa.gov/WWW/K-12/airplane/foil2.html>.

### **Elaborate**

*(PowerPoint Slide 18)*

The Lift formula illustrates how knowledge of mathematics is vital to understanding how airplanes fly.

Explain that the coefficient of lift is a dimensionless factor that relates force to pressure. It can decrease and increase depending on the angle of attack (angle of the plane up or down), so it has a minimum and maximum value. The minimum values are calculated from level flight (zero angle of

attack) whereas the maximum values occur just before the plane stalls (nose angled up). Wind tunnel simulations usually create these values.

Use the following prompt. Have the students work in groups to explore their understanding of Lift:

- What is the F/A-18A's lift while it flies at 700 mph, the air density is 1.31 g/L, and the lift coefficient is 1.8?

After a few minutes, follow-up and have the students reflect on why they utilized their criteria.

**Evaluate**

*(PowerPoint Slides 19-20)*

Students are challenged to apply the Lift Formula to flight scenarios in which the value of variables is provided. The first scenario is a direct application of the formula as presented in the slideshow. Point out that data are provided in English units and students should use the numbers outside of the parentheses to do their calculations. The correct value of lift is 986,144 lb.

The second scenario requires additional reasoning. You may wish to point out that in order to hold a constant flight level, the lift must equal the weight of the plane. You may also need to point out that we are using the weight of the plane on the ground, but that the difference in weight at flight level and ground level is less than 1%. To calculate the speed, the students will need to rearrange the Lift Formula algebraically. They should get

$$v = \sqrt{\frac{2F_L}{\rho C_1 A}}$$

Point out that by using the English units not in parentheses given in the scenario, the calculated speed will be in feet/second. The correct speed is 316 feet/second (215 mi/hr).

## **PART 2**

### **Explain**

*(PowerPoint Slides 22-24)*

Part 2 of this lesson presents the Engineering Design Process (EDP) and guides the students through the design and construction of a working prototype of an aircraft. The prototype must meet the specifications described in PowerPoint Slide 22, and the students are constrained to using only the materials provided. The instructor should collect enough materials for the class in advance of presentation of this lesson.

2. Introduce the EDP (slide 24). Briefly describe the eight stages of the process.
  - a. Identify the Problem
  - b. Identify Criteria or Constraints
  - c. Brainstorm Possible Solutions
  - d. Generate Ideas
  - e. Explore Possibilities
  - f. Select an Approach
  - g. Build a Model or Prototype
  - h. Refine the Design

Discuss with the class each of the steps in the EDP, soliciting individual interpretations of each step in the context of aircraft design.

Explain that the class will work in groups and follow these steps, and that each person must document the activities in his or her journal.

### **Elaborate**

*(PowerPoint Slides 25-26)*

Divide the class into groups of four. Collectively guide the groups through the first two steps of the process – *Identify the Problem* and *Identify Criteria and Constraints*. Emphasize that groups are constrained to using only the materials provided.

### **Explore**

*(PowerPoint Slides 27)*

Convene the groups and have them review the first two steps of the design process. Tell them to record in their journals their problem and the criteria and constraints. Reinforce to them that as they proceed, they should record all of their activities in their journals. Then, let the groups proceed individually to complete the rest of the steps in the EDP.

**Evaluate**

When the groups have completed their designs and constructions, perform a mock competition to demonstrate the performance of each of the prototypes. Have each group launch their aircraft using the catapult they designed, measure the maximum horizontal distance of flight, and time the total length of the flight. When measuring flight distance, be sure to take into account *only* the horizontal distance. This can be done by marking off 10 foot lengths on a roll of string that is at least 200 feet long. Use a stopwatch or computer to measure flight duration. Choose a criterion for determining the end of the flight. The simplest way to determine the end time is to record the time at which the plane hits the ground.