LESSON PLAN

TITLE: CENTER OF GRAVITY, PITCH, YAW

GRADE RANGE: 9-12

SUBJECT: SCIENCE

BENCHMARK: SC.C.1.4.1—The student knows that all motion is relative to whatever frame of reference is chosen and that there is no absolute frame of reference from which to observe all motion.

DESCRIPTION OF THE LESSON: Students will measure and calculate 25 percent of the average wing chord using the drawing of the F-15 ACTIVE. Using this calculation they will find the center of gravity. Students will then put together a model of the F-15 ACTIVE and label the diagram based on two views, one showing pitch, the other showing yaw.

BACKGROUND INFORMATION: To find the center of gravity, engineers weigh the aircraft, usually at the wheel points, then calculate the balance point of the airplane. For conventional airplanes, this is usually approximately 25 percent of the average wing chord along the center line of the fuselage. When the plane moves in the pitch axis, the plane moves around the center of gravity, with the nose going up or down. In current aircraft designs this is accomplished with the use of the elevators. Elevators can be part of the horizontal tail or, as on the F-15 ACTIVE, the entire horizontal tail can move to serve as elevators. Similarly, when the plane moves in the yaw axis, it rotates around the center of gravity, with the nose moving left or right. Research was conducted on how thrust vectoring affects pitch and yaw control on the F-15 ACTIVE. Like the elevators and rudder, pitch and yaw are changed by altering the angle of thrust. In addition to thrust vectoring, the F-15 ACTIVE has canards forward of the wings, which are also used to change pitch.

MATERIALS (per group of students)

- 1 F-15 ACTIVE paper model
- 1 metric ruler
- 1 calculator
- 4 small brass paper fasteners
- 1 pair of scissors

ESSENTIAL QUESTION (PROBLEM STATEMENT): How does the center of gravity of an airplane affect thrust vectoring, pitch, and yaw?

OPENING: As a whole group, have the students stand and try to balance themselves on one leg. Discuss the difference between standing on two legs and balancing on one leg.

STEPS TO DELIVER LESSON (Please see pages 50-56 in Exploring the Extreme Educator's Guide—Lesson 3: Center of Gravity, Pitch, and Yaw)

1. Arrange class into groups of 4 students.
2. Use a metric ruler to demonstrate how to find the center of gravity of an object.
3. Find the center of gravity of the F-15 ACTIVE by measuring the width of the wing at different points on the wing.
4. Calculate the average width of the wing.
5. Locate the center of the aircraft lengthwise.
6. Locate the center of gravity of the aircraft.
7. Cut out another model of the F-15 ACTIVE. Assemble model using brass fasteners.
8. Pose the aircraft in pitch or yaw.

LESSON CLOSURE: As a whole class, discuss data. Compare and contrast pitch and yaw and the parts of the airplane that control pitch and yaw.

HOME LEARNING: Design and construct a model paper airplane. Find the center of gravity of your model airplane.

Lesson 3: Center of Gravity, Pitch, Yaw

Objective

- Find the center of gravity and discover its relationship to thrust vectoring, pitch, and yaw.

Science Standards

Physical Science
Position and Motion of Objects
Unifying Concepts and Processes
Evidence, Models, and Explanation
Science and Technology
Technological Design Abilities

Science Process Skills

Measuring
Making Models

Mathematical Standards

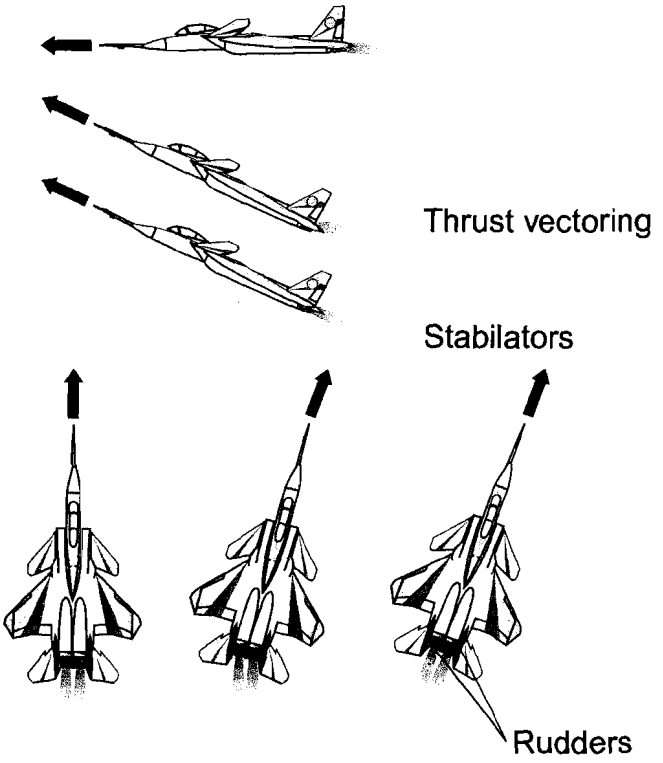
Connections
Computing and Estimating
Measuring

Management

This lesson works well with students working individually but helping each other through the construction section. Allow approximately two 40- to 45-minute class periods to complete. This lesson is divided into two parts. In part 1, students will calculate the location of the center of gravity using the average wing chord formula. Once this has been calculated, the students will mark the center of gravity's location on the picture of the plane from lesson 2. The students may need to use a paper clip to make sure the plane balances at the 25% chord point. In part 2 the students construct a model of the F-15 ACTIVE by marking the center of gravity on the smaller pictures, cutting out the two views of the planes and the engines, and attaching them to the student worksheet. Following a discussion of center of gravity, pitch, and yaw, the students will label the two pictures to show their understanding of pitch and yaw and correctly label the position of the center of gravity.

Background Information

To find the center of gravity, engineers weigh the aircraft, usually at the wheel points, then calculate the balance point of the airplane. For conventional airplanes, this is usually approximately 25 percent of the average wing chord and along the center line of the fuselage. When the plane moves in the pitch axis, the plane moves around the center of gravity, with



Thrust vectoring

Use of propulsion controls in place of aerodynamic controls

the nose going up or down. In current aircraft designs this is accomplished with the use of the elevators. Elevators can be part of the horizontal tail or, as on the F-15 ACTIVE, the entire horizontal tail can move to serve as elevators. Similarly, when the plane moves in the yaw axis, it rotates around the center of gravity, with the nose moving left or right. Research was conducted on how thrust vectoring affects pitch and yaw control on the F-15 ACTIVE. Like the elevators and rudder, pitch and yaw are changed by altering the angle of thrust. In addition to thrust vectoring, the F-15 ACTIVE has canards forward of the wings, which are also used to change pitch.

Description

Students will measure and calculate 25 percent of the average wing chord using the drawing of the F-15 ACTIVE from lesson 2. Using this calculation they will find the center of gravity. Students will then put together a model of the F-15 ACTIVE and label the diagram based on two views, one showing pitch, the other showing yaw.

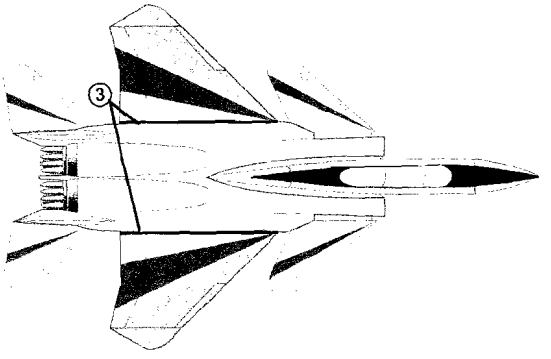
Part 1

Materials and Tools

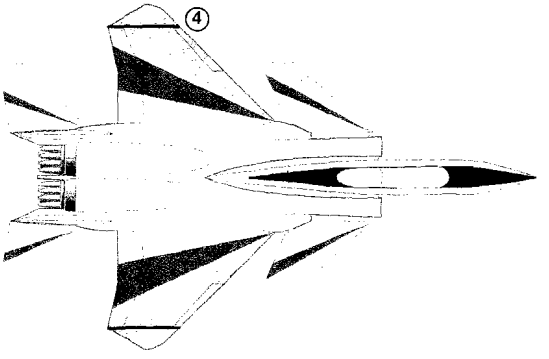
- Paper model of F-15 ACTIVE from lesson 2 on page 21.
- One metric ruler per student
- Calculators
- One copy of the Student Work Sheet Part 1 for each student (see page 54).
- Optional: an overhead copy of the F-15 ACTIVE pattern from lesson 1, page 21, for teacher use

Procedures

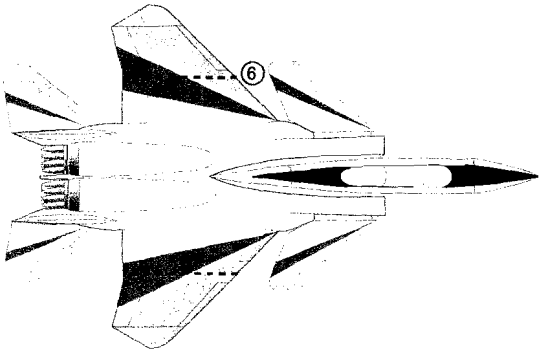
1. Have the students balance their ruler on one finger, moving the ruler back and forth until it is level. Explain that this is one way to find the center of gravity of an object.
2. Ask the class if they have any idea how engineers find the center of gravity of an airplane. Lead them to the use of a formula to calculate the center of gravity.
3. The students will do this using their pattern from lesson 1 (page 21). To find the center of gravity, first they need to measure the width of the wing next to the fuselage to the nearest millimeter. Record this number on the Student Work Sheet on page 54.



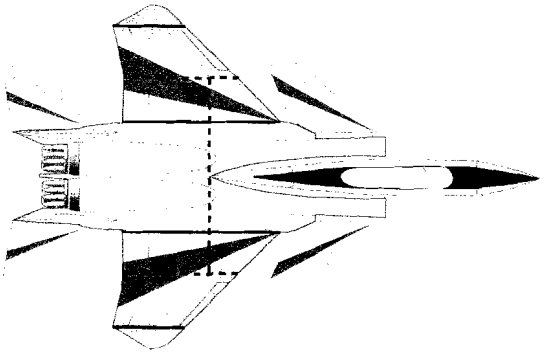
4. Next, measure the width of the wing at the wing tip and record this measurement.

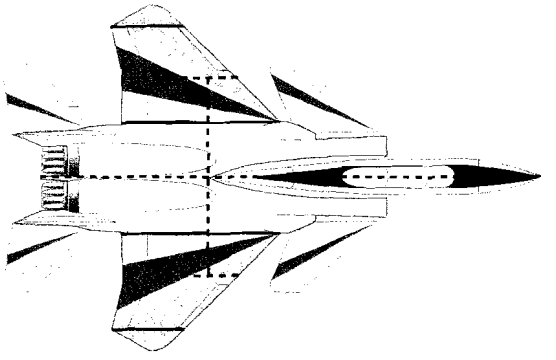


5. Have the students calculate the average wing chord by adding the two measurements, then dividing the answer by two. Record the answer on the student worksheet.
6. Using the ruler, making sure it is placed parallel to the fuselage, locate the section of the wing that matches the width of the average wing chord.



7. Students should draw a line across the wing at this point.
8. Next the students will calculate 25 percent of the length of the wing chord.
9. Mark the 25 percent wing chord distance on the line they drew for the average wing chord. This distance should be measured from the front, or leading, edge of the wing. Do this on both wings.
10. Use a straight edge to draw a line connecting the two dots.
11. To find the center of the plane lengthwise the students can simply fold the plane in half, making sure to match the edges.
12. Mark a large dot on the plane where the center lengthwise fold and the line connecting the wing chords intersect. This is the center of gravity.





Part 2

Materials and Tools

- F-15 ACTIVE model from lesson 1 (page 21).
- One cardstock copy of top and side view of F-15 ACTIVE and engines per student (see page 56).
- 4 small brads or paper fasteners per student
- Scissors
- One copy of the center of gravity, pitch, and yaw worksheet per student (see page 55).

Procedures

1. Discuss the direction the tail and nose moved when the thrust was directed left or right in lesson 2. This is yaw.
2. Check for understanding by having the students hold up their planes and demonstrate the motion when changing yaw.
3. Explain that pilots change the yaw during crosswind landings. If a wind is blowing across the runway the pilot will need to change the yaw to compensate for the push of the wind across the plane. This will allow the pilot to land safely.
4. Discuss the direction the tail moved when the thrust was directed up or down in lesson 2. This is pitch. Pitch also controls the movement of the nose of the plane. When the tail moves up the nose points down. When the tail is down the nose points up. Because of the necessity of holding the plane by the nose, the students could not see the movement of the nose during this portion of lesson 2.
5. Check for understanding by having the students hold up their planes and demonstrate the motion when changing pitch.
6. Explain that pilots change the pitch in order to change the angle of attack of the plane, which affects the amount of lift generated by the wings.
7. Construct the model of the F-15 ACTIVE following the directions below and on the Student Work Sheet.
8. Mark the center of gravity on the top and side views of the F-15 ACTIVE.
9. Cut out the F-15 ACTIVE views and engines.
10. Attach the engines to the plane using one brad for each view. Put the brads through the dots on the engine pieces and the engine area on the plane. This will simulate the thrust vectoring of the F-15 ACTIVE.
11. Attach the cutouts to the work sheet using the remaining brads by putting the brads through the center of gravity of each plane and then through the work sheet.
12. Label each view as showing either pitch or yaw and explain the purpose of pitch and yaw.

Assessment

Collect and review the work sheets.

Extension

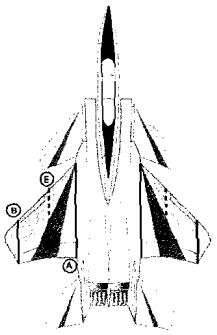
Have students research pitch and yaw, and how they relate to flight.

Student Work Sheet Part 1
Name:_____
Date:_____

Finding Center of Gravity

Follow these steps to find the desired location for the center of gravity for the F-15 ACTIVE.

1. Measure the distance from the leading edge to the trailing edge of the wing:



A. Next to the fuselage _____

B. At the wing tip _____

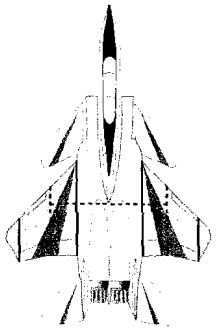
C. Add _____

D. Divide by 2 ÷ 2

E. Average wing chord _____

2. Use your ruler to locate the position on the wing that matches the length of the average wing chord you just calculated. Use the ruler to draw in the average wing chord. Make sure it is parallel to the fuselage.

3. Calculate the desired location of the center of gravity:



A. Average wing chord (from letter E) _____

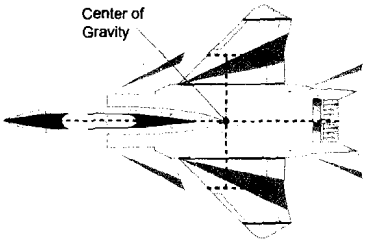
B. Find 25 percent of average wing chord x 0.25

C. Answer _____

4. Put a dot this distance back from the leading edge of the wings on both of your average wing chord marks. Use a straight edge to connect these two dots.

5. Fold your F-15 ACTIVE in half lengthwise to find the center axis.

6. Where the fold and the line connecting the 25 percent marks intersect is the location of the center of gravity for the F-15 ACTIVE. Put a large dot here.



Student Work Sheet Part 2

Name:_____

Date:_____

Center of Gravity, Pitch, and Yaw Work Sheet

Directions

1. Mark the center of gravity on the top and side views of the F-15 ACTIVE.
2. Cut out the F-15 ACTIVE views and engines.
3. Attach the engines to the plane using one brad for each view. Put the brads through the dots on the engine pieces and the engine area on the plane. This will allow the engines to move and simulate the thrust vectoring of the F-15 ACTIVE.
4. Attach the cut-outs to the work sheet using the remaining brads by putting the brads through the center of gravity of each plane and then through the work sheet.
5. Label each view as showing either pitch or yaw and explain how pitch and yaw affect the flight of an aircraft.

(attach plane here)

(attach plane here)

F-15 ACTIVE TEMPLATE