

G r a d e s K - 4



Lesson 1: Finding the Center of Gravity Using Rulers

Grades K–4

Objectives

- To discover the center of gravity (c.g.) by balancing a cardstock shape (two-dimensional model) of an F-15 ACTIVE on a ruler both longitudinally and laterally.
- To demonstrate balance (state of equilibrium) by suspending a cardboard shape of an F-15 ACTIVE from a string at the center of gravity (c.g.).

Science Standards

Scientific Enterprise
Science and Technology
Science as Inquiry
Physical Science
Position and Motion of Objects
Change, Constancy, and Measurement
Evidence, Models, and Explanation

Science Process Skills

Observing
Communicating
Measuring
Collecting Data
Inferring
Predicting
Hypothesizing
Investigating

Mathematical Standards

Problem Solving
Communication
Reasoning
Measuring

Management

This lesson may be a whole class lesson. For kindergarten and first grade students, the teacher may demonstrate using one cardstock model of an F-15 ACTIVE. Students in grades 2-4 may each have their own cardstock model or work in small groups of two to four sharing a cardstock model.

This lesson is divided into two parts. In part 1, students draw longitudinal and lateral axes to find the center of gravity. In part 2, students may need help to suspend models. The models are needed for lesson 3, and part 2 may be postponed until lesson 3 is scheduled. Allow approximately 30 to 45 minutes to complete.

The center of gravity is the average location of the weight of the aircraft. The mass and weight are distributed throughout the airplane.

Part 1

Materials and Tools

- Cardstock F-15 ACTIVEs (see page 21) for each student or group
- Ruler for each group
- Crayon
- Masking tape
- Scissors

Preparation

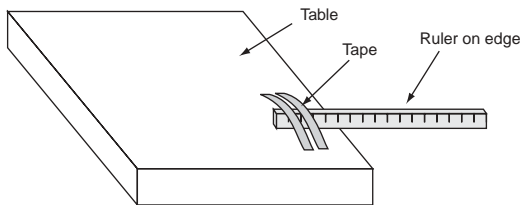
Teacher uses the pattern to trace and cut out F-15 ACTIVE models from light cardstock (see page 21). If students are capable, they can cut out their own models.

Procedure

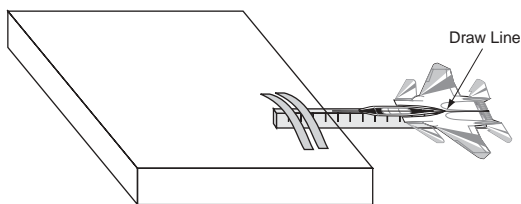
1. Ask students what they know about the F-15. (It is a highly maneuverable fighter capable of achieving Mach 2 and high altitudes. Explain that the F-15 ACTIVE was a special one-of-a-kind airplane flown by NASA and U.S. Air Force research pilots for research purposes.)
2. Bring out a cardstock F-15 ACTIVE model. Balance it flat on your finger or fist. Ask the students if they think they could balance it too. If using one model to demonstrate, give several students a chance to balance it, or distribute the cardstock F-15 ACTIVEs. Allow time for experimentation.



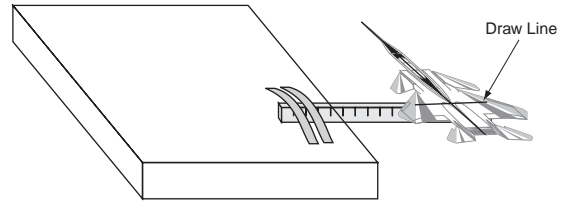
3. Tell students that NASA engineers need to know the exact place to balance the real airplane, just as they balanced their model airplanes. This place is called the center of gravity (c.g.). Balance an F-15 ACTIVE model on your finger. Tell students this is a stable position—when given a little push—it wobbles back and forth, but doesn't fall. It will come back to a stable, balanced position. Tell them NASA engineers use science and mathematics to find the center of gravity (c.g.), and they can do it too.
4. Tell students they will balance the F-15 ACTIVE models on the edge of a ruler instead of on their fingers. Demonstrate how to position the ruler on the edge of a table and tape it in place with masking tape.
5. Most of the ruler's length should extend past the edge of the table.
6. Demonstrate how to balance the cardstock F-15 ACTIVE on the ruler in a longitudinal direction. Draw a line down the middle of the F-15 ACTIVE with a crayon.



7. Demonstrate how to balance the F-15 ACTIVE on the ruler in a lateral direction. Draw a line.



8. The point of intersection of the two lines is the center of gravity (c.g.).

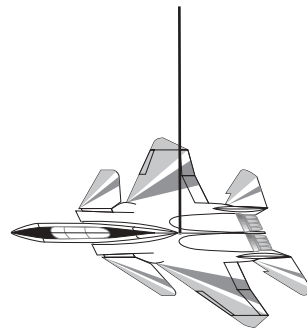


9. Distribute tape and rulers to each group. Students will tape the ruler to a desk and take turns helping each other balance and hold the F-15 ACTIVE steady so lines may be drawn. This could be a learning center with an adult helper. Save F-15 ACTIVE for part 2.

Part 2

Materials and Tools

- Cardstock F-15 ACTIVE from part 1
- Crayons
- Needle and string for teacher
- Paper clips
- Ceiling hooks
- Meter sticks or rulers



Procedures

1. Allow students to color their F-15 ACTIVEs using the colors of red, white and blue. Use the Exploring the Extreme poster as a color guide or look on-line at www.spacelink.nasa.gov. Teacher punches a small hole in each F-15 ACTIVE at the center of gravity with the needle and thread.
2. Tie a large knot on the bottom of the string. The knot must be larger than the hole.
3. Hang from ceiling using paper-clip hooks or suspend from meter stick/ruler, which will be held by the teacher or partner. Save F-15s for lesson 3.

Assessment

1. Conduct a class discussion where students demonstrate their understanding of:
 - Balance
 - Stability
 - Center of gravity
2. Ask students to predict what they think might happen if the teacher pushes the F-15 ACTIVE in:
 - A forward direction
 - A sideways direction
3. Push the F-15 ACTIVE and allow it to swing back to a resting position. Discuss the action in terms of balance and stability. Compare the push to a pilot flying (controlling) the airplane and the airplane being designed to return to a stable position. The F-15 ACTIVE uses computers to integrate the control surfaces and the vectored thrust so that the plane is stable.

Management

In part 1, students may work individually or in pairs using their F-15 ACTIVE models from lesson 1 or lesson 2. Using just one suspended cardstock F-15 ACTIVE model, the teacher may demonstrate part 1.

In part 2, students working in pairs or groups of three will be able to help each other. Allow 20–30 minutes for part 1, and 45 minutes for part 2.

Description

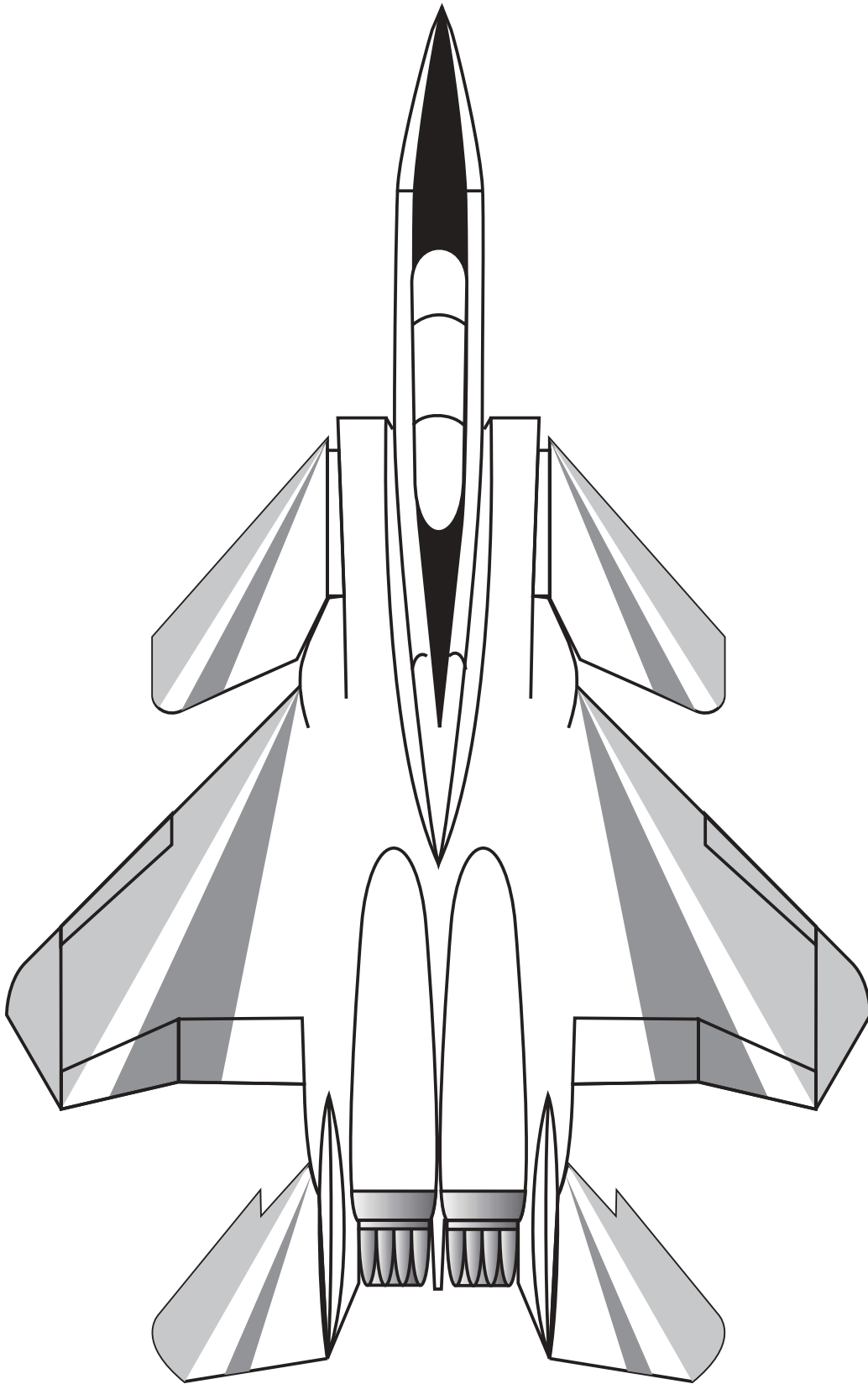
Students discover the center of gravity of a cardstock shape of an F-15 ACTIVE using plumb lines and suspend the F-15 ACTIVE from a string.

Materials and Tools

- Cardboard F-15 ACTIVEs
- String for each group, 18 inches (45.72 centimeters)
- Hole punch for each group
- 2 pushpins
- Paper clip for each group
- Ruler for each group



Drawing of F-15 ACTIVE
(Teachers, copy this page on to cardstock.)



Lesson 2: Finding the Center of Gravity Using Plumb Lines

Grades 3–4

Objectives

- To discover the center of gravity (c.g.) of a cardstock shape (two-dimensional model) of an F-15 ACTIVE using plumb line.
- To demonstrate balance (state of equilibrium) by suspending a cardstock shape of an F-15 ACTIVE from a string at the center of gravity.

Science Standards

Scientific Enterprise
Science and Technology
Science as Inquiry
Physical Science
Position and Motion of Objects
Change, Constancy, and Measurement
Evidence, Models, and Explanation

Science Process Skills

Observing
Communicating
Measuring
Investigating
Predicting
Controlling Variables

Mathematical Standards

Problem Solving
Communicating
Reasoning
Measuring
Functions and Patterns



Preparation

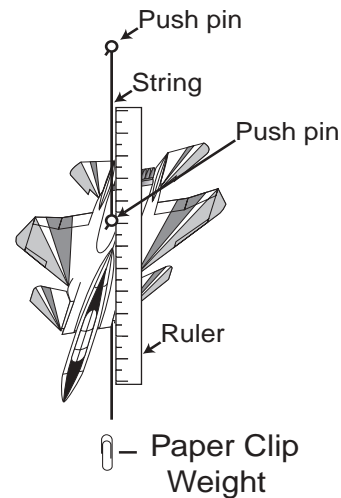
Use the pattern of the F-15 ACTIVE to trace and cut out cardboard shapes. Older students can do the cutting.

Part 1

1. Introduce the F-15 ACTIVE
 - Ask students what they know about the F-15 ACTIVE. (A highly maneuverable fighter capable of achieving over Mach 2 and altitudes of 60,000 feet.) Bring out one of the cardstock F-15 ACTIVEs. Explain this as an F-15 ACTIVE, a special one-of-a-kind airplane flown by NASA test pilots for research purposes.
 - Balance it flat on your finger. Ask the students if they think they could do the same if they had an F-15 ACTIVE. Challenge students.
 - Distribute cardboard F-15 ACTIVEs or distribute materials so students can cut out the F-15 ACTIVEs.
 - Allow time for exploration as students will want to fly their airplanes.
 - Tell students that NASA engineers need to know the exact place to balance the F-15 ACTIVE just as the students did when they balanced the models on their fingers.
 - Tell them NASA engineers use mathematics to find the center of gravity, and they can, too.
 - Students will do each step in small groups, or teacher may demonstrate.

Procedure

1. Attach the paper clip weight to one end of a string.



2. Attach the string and paper clip weight to a wall with a pushpin. This is the plumb line.
3. Punch one hole anywhere on the F-15 ACTIVE.
4. Put the other pushpin through the hole, and let the F-15 ACTIVE dangle from the pin until it settles in a stable position.
5. Put the pushpin (and hanging F-15 ACTIVE) right on the plumb line.
6. Use a ruler to draw a line on the F-15 ACTIVE, following path of the plumb line.
7. Repeat steps 3, 4, 5, and 6 once or twice. Take turns.
8. Where the lines intersect is the center of gravity.



Part 2

Have the students color their F-15 ACTIVEs and punch a small hole in each F-15 ACTIVE at the marked center of gravity with a needle and thread. Tie a large knot at the bottom. Hang from the ceiling using paperclips or hooks. Hang the F-15 ACTIVEs low enough so that students can use them to complete lesson 3.

Assessment

1. Conduct a class discussion where students demonstrate their understanding of:
 - Balance
 - Stability
 - Center of Gravity
2. Ask students to predict what they think might happen if the teacher pushes the F-15 ACTIVE in:
 - A forward direction
 - A sideways direction
3. Push the F-15 ACTIVE and allow it to swing back to a resting position. Discuss the action in terms of balance and stability. Compare the push to a pilot flying (controlling) the airplane and the airplane being designed to return to a stable position. The F-15 ACTIVE uses computers to integrate the control surfaces and the vectored thrust so that the plane is stable.

Extensions

Use other shapes to find center of gravity. For example: initials, outlines of states, birds.



Lesson 3: Changing the Center of Gravity Using Moment Arms

Grades 3–4

Objectives

- To discover that the center of gravity (c.g.) can be changed by adding weights to the balanced F-15 ACTIVE model.
- To calculate moment arms using weights on a yardstick.

Science Standards

Unifying Concepts and Processes in Science
Science as Inquiry
Physical Science
Positions and Motion of Objects
Science and Technology
Science in Personal and Social Perspectives
History and Nature of Science

Science Process Skills

Observing
Communicating
Measuring
Investigating
Predicting
Collecting Data
Inferring
Hypothesizing

Mathematical Standards

Problem Solving
Communicating
Reasoning
Computing and Estimating
Measuring
Functions

Management

In part 1, students may work individually or in pairs. In part 2, students working in pairs or groups of three will be able to help each other. Allow 20-30 minutes for part 1 and 45 minutes for part 2.

Description

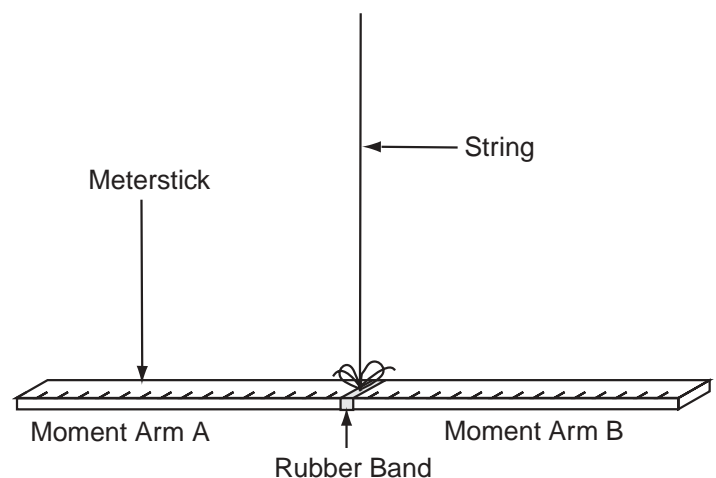
Students discover the center of gravity can be changed by adding paper clips to the balanced F-15 ACTIVE cardboard model.

Students calculate the moment arm using a balanced yardstick, adding weights at measured differences.

Materials and Tools

For each group:

- Yardstick
- Rubber band
- String
- Cellophane tape or masking tape
- Ruler
- Weights:
 - Government Standard weight set (1, 2, 3 grams) or
 - Fishing sinkers of known weigh (1, 2, 3 ounces) or
 - Fishing sinkers all one size per group
- Copy of chart for each student



Preparation

The teacher may want to arrange the hanging yardsticks before class time. Each group will use a suspended yardstick. Wrap a rubber band around each yardstick. Tie a string to the rubber band to suspend the yardstick. Move the rubber band until the yardstick is balanced. Rubber band is at the 0 point and measurements will be made in both directions, called arms, starting at this point. Explain that moment is equal to weight x moment arm (distance). Calculate moments for tests 1-4.

1. Tell students to place a 1-unit weight 2 inches (5.08 cm) from the 0 point. They should tape it to the yardstick. Suspend the yardstick. It will be unbalanced. Tell students to find out how much weight needs to be placed at 1 inch (2.54 cm) from the 0 point on the other side to make the yardstick balance. Record the answer on chart. (*2 units weight*)
Discussion: Ask if the larger weight is closer or farther away from 0 point. Will this always be true? (*Yes, the larger weight is always closer to the 0 point.*)
2. Tell students to put 2 units of weight at 6 inches (15.24 cm) from the 0 point. Ask them to find what weight needs to be added at 4 inches (10.16 cm) from the 0 point on the other side. Record the answer. (*3 units weight*)
Discussion: The distance the weight is from the 0 point is called the moment arm. One side is called weight A on moment arm A and the other side is weight B on moment arm B. Look at chart.

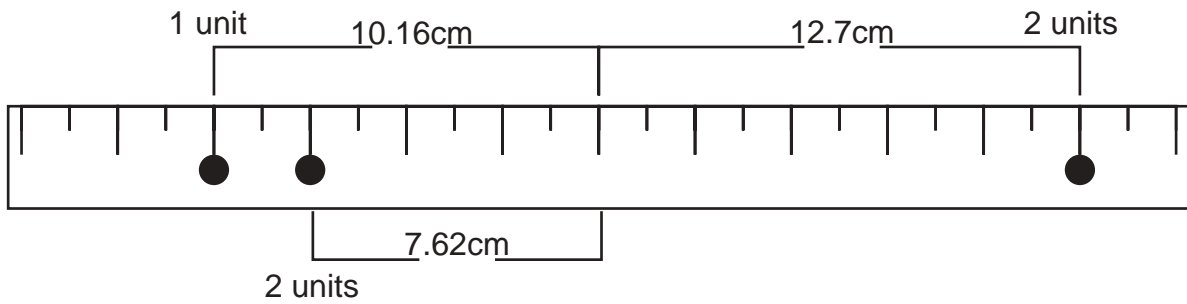
3. Tell the students to put 3 units of weight 4 inches (10.16 cm) from 0 point. (3 units weight at 4 inches or 10.16cm moment arm.) Ask where they could put a 1-unit weight to make the yardstick balance. Record the answer. (*12 units*)
4. Put 2 units of weight on one side to make the yardstick balance. It will be easier if students use even measurements. Record the answer. Discussion: Ask if students notice a connection between moments A and B.
 - How do you find moment?
 - What is the difference between moment and moment arm?
5. Let students experiment with weights to get other moments.
Enrichment: Challenge students to add weights to two different spots on the same side.
Weight $A_1 \times \text{Moment arm}_1 + \text{Weight } A_2 \times \text{Moment arm}_2 = \text{Weight B} \times \text{Moment arm B}$
 $1 \times 4 + 2 \times 3 = 2 \times 5$

Assessment

Discussion and Student Sheet



A	B
1. $1 \times 2 = 2$	1. $2 \times 1 = 2$
2. $2 \times 6 = 12$	2. $3 \times 4 = 12$
3. $3 \times 4 = 12$	3. $1 \times 12 = 12$
4. $2 \times 3 = 6$	4. $3 \times 2 = 6$ (possible answer)
5. $2 \times 6 = 12$	5. $3 \times 4 = 12$ (possible answer)
6. $2 \times 9 = 18$	6. $3 \times 6 = 18$ (possible answer)



Name: _____

Date: _____

Moment Student Work Sheet

Test #	Weight A (Grams)	Distance A (Moment Arm A, Centimeter)	Moment A (Grams centimeter)	Weight B (Grams)	Distance B (Moment Arm B, centimeter)	Moment B (Grams centimeter)
#1	28.35g	5.08cm		56.7g	2.54cm	
#2	56.7g	15.24cm		85.05g	5.08cm	
#3	85.05g	10.16cm		28.35g	30.48cm	
#4	56.7g	7.62cm				
#5						
#6						
#7						



Name: _____

Date: _____

Enrichment

Calculate these moments. Use calculators if appropriate.

Item	Weight (Kilograms)	Moment Arm (Meters)	Moment Kilograms
Fuel in tank 1	4409.2 (9720 lbs.)	32.808 (1291 in.)	
Fuel in tank 2	2204.6 (4860 lbs.)	16.404 (645 in.)	
Fuel in tank 3	3306.9 (7290 lbs.)	13.1232 (516 in.)	
Fuel in tank 4	2204.6 (4860 lbs.)	26.2464 (1033 in.)	
Instruments	209.437 (461 lbs.)	9.8424 (387 in.)	
Pilot (Student Weight)		16.404 (645 in.)	



