Lesson 2: Vectoring
Grades 5 - 8

Objective
- Discover how vectoring the thrust from a jet engine affects movement of an airplane.

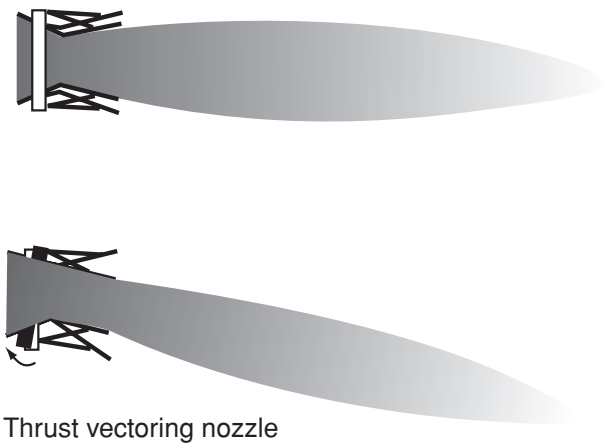
Science Standards
Physical Science
Position and Motion of Objects
Unifying Concepts and Processes
Evidence, Models, and Explanation
Science and Technology
Technical Design Abilities

Science Process Skills
Observing
Communicating
Collecting Data
Predicting
Inferring
Making Models
Controlling Variables
Investigating

Mathematical Standards
Communicating
Reasoning
Geometry

Management
This lesson can be done with the students working in pairs or individually. Allow approximately 40-45 minutes to complete. The activity in divided into two parts. In part 1 the students will cut out the picture of the F-15 ACTIVE template on page 56, put together the balloon engine, and attach it to the template. In part 2 students will control the direction of the thrust from the balloon by bending the flexible straw in different directions. This experiment stresses prediction, data collection, and analysis of results.

Background Information
Controlling and directing the angle of the thrust that comes out of an engine is called thrust vectoring. This is the purpose of the F-15 ACTIVE research project. Thrust vectoring will make future aircraft more maneuverable and more fuel efficient. Currently thrust can be vectored at a 20° angle in any direction. Also, the two engines can work independently of each other, meaning the nozzle thrust can be angled different directions at the same time. Thus the airplane's roll, yaw, and pitch can be controlled in this way. This is an application of Newton's Third Law of Motion: for every action there is an equal but opposite reaction.



Thrust vectoring nozzle

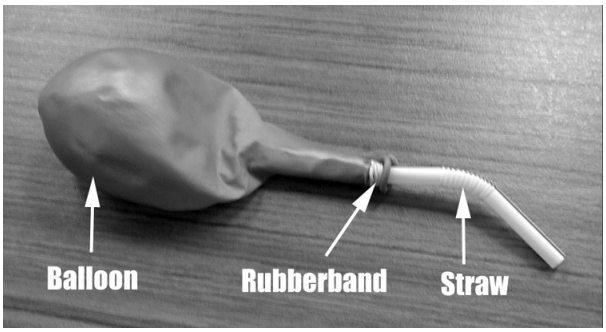
Description
Students cut out a copy of a picture of the F-15 ACTIVE, tape a balloon and flexible straw "engine" to the plane, and conduct a series of experiments by changing the angle of the straw. This is a simulation of thrust vectoring.

Part 1
Materials and Tools

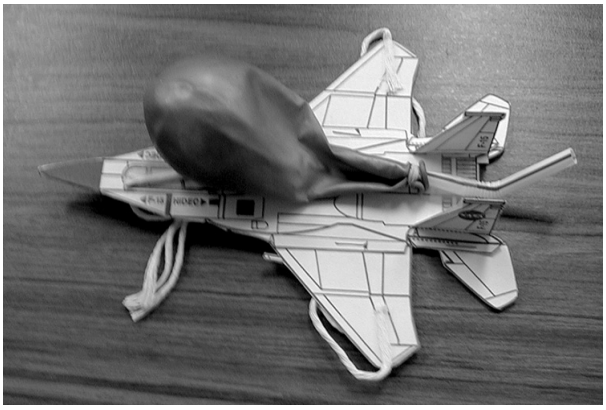
- One 8-by-10-inch F-15 ACTIVE template on page 56, photocopied on cardstock, per student
- One balloon per student
- One 1-inch section of 1/4-inch rubber tubing per student (example: fish tank tube).
- One small rubber band per student
- One pair of scissors per student
- Tape
- Three 8-inch pieces of string per student
- One copy of the Student Work Sheet per student

Procedures

1. Cut out the picture of the F-15 ACTIVE on page 56. Set aside.
2. Cut the straw so there is about 1 inch between the flexible section and each end of the straw.
3. Cut a 1/2-inch slit in one end of the straw. Gently push one end of the rubber tubing into the end of the straw with the slit. This will keep the straw from collapsing when the rubber band is wrapped around it.
4. Slide the neck of the balloon over the end of the straw with the rubber tubing in it.
5. Wrap the rubber band around the balloon, the straw, and the rubber tubing. This will create an airtight seal and allow the balloon to be inflated.

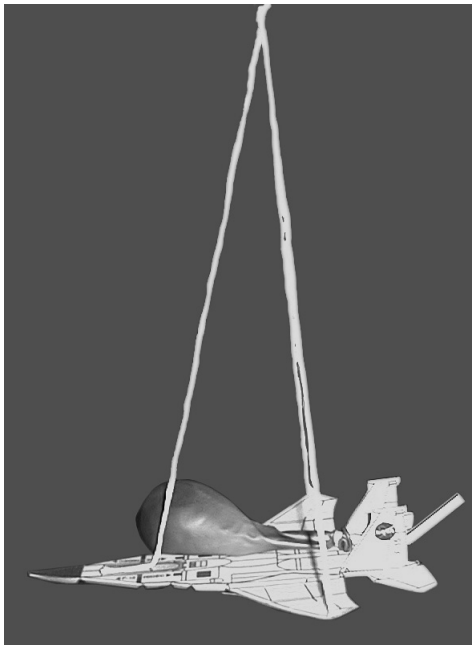


6. Position the balloon engine on the plane so that the flexible section of the straw extends beyond the edge of the plane. The balloon should rest on the plane. Tape the engine to the plane across the rubber-banded section.
7. Using the scissors, carefully poke a hole in the plane approximately where the cockpit is and one near the tip of each wing. See



hole locations marked on the template on page 56.

8. Thread one end of each piece of string through the holes. Tie a knot in each string underneath the plane to keep it from slipping off.



9. Gather the free ends of the string together, adjust them so the plane hangs level, and tie or tape the ends together.

Part 2

Materials and Tools

- Completed F-15 ACTIVE model from part 1
- Student Work Sheet on pages 48 and 49

Procedures

1. Tell the students they are going to do an experiment to find out how the plane will react when the direction of the thrust from the balloon is changed.
2. Provide each student with a copy of the Student Work Sheet on pages 48 and 49. Instruct them to record their predictions, giving as much detail as possible, prior to conducting the experiments.
3. Ask the students to predict what they think might happen when the balloon is inflated and pinched shut, the straw is pointed at a 20^{o} angle left, and then the straw is released so the air is forced out of the balloon through the straw. Give them time to record their predictions.
4. Have the students conduct the experiment and record their observations on the Student Work Sheet.
5. Repeat the experiment with the straw bent 20^{o} to the right. Make sure they record their predictions first.
6. Next, have them conduct the experiment with the straw pointed 20^{o} up, then again with the straw bent down. When they point the straw up or down, the students will need to hold the plane with their thumb and finger near the cockpit and not use the strings at all. Tell the students to pay attention to how the paper plane bends before inflating the balloon and while the balloon is deflating. The movement for these two experiments is very small, but can be detected, if they watch closely.
7. Discuss the results of each group's experiments. Did the predictions match the results? Why or why not?

Assessment

Collect and review student worksheets.

Extension

Construct two balloon engines and attach to the model to simulate the directional independence of the two F-15 ACTIVE engines.

Student Work Sheet (Part 2)

Name: _____

Date: _____

Experimenting with Thrust Vectoring

Complete these steps prior to conducting each experiment:

1. Describe the experiment in your own words.
2. Predict what will happen during the experiment. Do this *before* conducting the experiment.
3. Conduct the experiment.
4. Record your observations and give your opinion as to why the experiment worked as it did.

Thrust vectored 20º left

Describe the experiment:

_____

_____

Make your prediction:

_____

_____

Record your observations:

_____

_____

Thrust vectored 20º right

Describe the experiment:

_____

_____

Make your prediction:

_____

_____

Record your observations:

_____

_____

Thrust vectored 20º up

Describe the experiment:

_____
_____

Make your prediction:

_____
_____

Record your observations:

_____
_____

Thrust vectored 20º down

Describe the experiment:

_____
_____

Make your prediction:

_____
_____

Record your observations:

_____
_____