Lesson Title	Using STEM to Understand Air Flow
Length of Lesson	50 minutes
Created By	Emily Burtnett
Subject	Aerodynamics, Math SL, Physics
Grade Level	10^{th}, 11^{th}, 12^{th}, high school topics
State Standards	Advanced Algebra 4a
DOK Level	DOK 3
DOK Application	Apply simple probability and curve fitting to data. Use technology and regression analysis to determine appropriate quadratic and cubic functions modeling real-life data.
National Standards	Use content-specific tools, software and simulations (e.g., environmental probes, graphing calculators, exploratory environments, Web tools) to support learning and research; select and use appropriate tools and technology resources to accomplish a variety of tasks and solve problems. Routinely and efficiently use on-line information resources to meet needs for collaboration, research, publications, communications, and productivity.
Graduate Research Element	Air flows around various objects and tries to conform to the shape of the object. It is important to understand the principals of air flow in order to perform CFD simulations or make educated predictions. Air flow is essentially the basis of all aerospace engineering research.

Student Learning Goal:
Students will learn how air (fluids) flow around objects and how this can be applied to aircraft design. They will make prediction based on knowledge obtained in the Four Forces of Flight lesson and use hands-on experiments to understand them. Students will also have the opportunity to use FoilSim, to examine airflow around various shapes and determine the relationship between airspeed and lift of an object by interpreting data.

Materials Needed (supplies, hand-outs, resources):
Apple, candle with stand, matches or lighter, knife, graphing calculator, computers, FoilSim Java applet, worksheet (attached)

Lesson Performance Task/Assessment:
Students will observe and participate in an experiment that demonstrates how air flows around an object (an apple). They will then use FoilSim to build an airfoil and interpret

the data and using the regression equation, they will determine the relationship between airspeed and lift.

Lesson Relevance to Performance Task and Students:
Fluid dynamics is a complex phenomena which is difficult to solve numerically. The idea of an idealized fluid has been one method to solve simple fluid problems. Ideal fluids do not exist in nature, but can be used to gain insight to many practical problems. However, the concept breaks down in many problems which appear quite simple at first. Students will use a simple experiment to observe fluid dynamics in action. They will use technology to understand a more complex scenario and learn relationship about airflow and how it applies to real world scenarios.

Anticipatory Set/Capture Interest:
Lockheed Martin F-35 video. http://player.vimeo.com/video/3437045?autop
This video may seem irrelevant to the lesson, but it is very "cool" and will capture their attention immediately. It demonstrates that aerospace engineering is a very exciting field and there are constant developments being made every day. It will show students how important technology and math is in the real world by showing off the incredible capabilities of a modern aircraft, that was developed with the use of STEM. Students will realize the important to STEM.

Guided Practice:
Instructor will guide students through the apple blow demonstration. Video for instructor reference: http://wings.avkids.com/Movies/apple_hi.mov

1. Talk with students about the experiment and fire safety.
2. Light the candle and place the apple about 2 inches in front of the candle.
3. Let a number of students try to blow out the candle.
    a. What happens?
4. Now place the apple several inches in front of the candle.
5. Let the students try to blow out the candle as they did in step 3.
    a. What happens this time?
6. Now, slide the apple in half. Place the apple such that the flat side is facing away from the candle (and towards the students).
7. Let the students try to blow out the candle as they did in steps 3 and 5.
    a. What happens?
    b. Where does the air go?
8. Now, place the candle to the side of the apple and let the students blow at the apple. Be sure to place the candle only a couple of inches from the apple.
    a. What happens now?

Instructor will explain that when air encounters a bluff body, such as the apple, the air divides into two streams which flow around either side of the apple. However, the flow

cannot negotiate the turn around the rear of the body. This causes the flow to separate and form a wake behind the apple. If the candle is close enough to the apple, the candle will be blown out.

As the distance increases, the wake dissipates. As the wake dissipates, the velocity of the air decreases. Therefore, if the candle is farther away from the apple, the candle will not be blown out, but merely flicker a little.

When the apple is sliced in half, the air is still split into two streams, but the air is directed to either side. Since there is a sharp edge, instead of a smooth surface, the air mainly continues in the same direction and the wake is no longer formed behind the apple. However, when the candle is moved to the side of the apple, the candle will be blown out.
Instructor will then walk students through using FoilSim. Directions will be given to get it working on the students' computers. FoilSim is an interactive simulation software package that examines the airflow around various shapes of airfoils. As you chance parameters such as airspeed, altitude, angle of attack, thickness and curvature of the airfoil, and size of the wing area, the software calculates the lift. The package was created at the NASA Glenn Research Center.

FoilSim II is a Java applet program that executes inside the browser of your computer. IT is available at: http://www.grc.nasa.gov/WWW/K-12/airplane/foil2.html.

Independent Practice:
Students will be given an activity sheet and worksheet that they will do on their own, but will the option to work together in pairs. The worksheet is attached to this lesson. The instructor will be available to assist students as needed.

Using FoilSim, collect data into a chart and then enter this data into a graphing calculator to study the graph and function produced. Record your answers.

1. In FoilSim, choose Metric Units. Set the following input conditions:
    a. Airspeed = 0 km/hr
    b. Altitude = 0 m
    c. Angle = 0 degrees
    d. Thickness = 12.5%
    e. Camber = 5.0%
    f. Area = 10 sq m
2. Using the chart below, record the AIRSPEED and LIFT. By changing the airspeed, make at least 9 additional readings. Record these in the chart.
3. Enter you data into the **Lists** in your calculator. Set up **Stat Plot** so that the AIRSPEED is your independent variable and the LIFT is the dependent variable.

Graph the data on your calculator and make a sketch on the graph found in the worksheet.

4. In FoilSim, push the **Plots** output button and select **Lift vs. Speed**.
    a. How does this graph compare to yours?
5. What kind of function does this graph represent?
6. Using the regression equations from your calculator, determine the equation of best fit.
    a. a=_____
    b. b=_____
    c. c=_____
    d. R^2=_____
    e. Equation:_____
7. What does this equation tell you about the relationship between the change in LIFT and the change in AIRSPEED?
8. Using the graph and/or the equation, what would you predict the lift to be given an airspeed of 300 km/hr?

Remediation and/or Enrichment:
For remediation, students can observe as the instructor goes through the FoilSim activity and it can be a group activity. Individual IEPs will be supported.

For enrichment, the instructor can explain the components of an airfoil (thickness, camber, etc.) and the NACA airfoil naming scheme.

Check(s) for Understanding:
Can the students communicate what they observed from the Apple Blow experiment? Can they explain the relationship between airspeed and lift?

Closure:
Review the four fundamental forces of flight with students and summarize what was done in the activities (Apple Blow and FoilSim). Students will be asked questions and the instructor will lead a group discussion. It would be good to prepare students for an upcoming lesson on aerospace mathematics that will be done later in the unit.

Possible Alternate Subject Integrations:
Physics, Algebra II, computer science

Teacher Notes:
FoilSim: http://www.grc.nasa.gov/WWW/K-12/airplane/foil2.html
F-35 Video: http://player.vimeo.com/video/3437045?autop
Apple Blow: http://wings.avkids.com/Movies/apple_hi.mov