STEM Connections

Connecting Science, Technology, Engineering, and Math concepts to our everyday lives.

Wind Tunnel

Fluid air dynamics

What is the most efficient design for seeing laminar and turbulent flow? How would you modify the design to improve the function of the wind tunnel? How would you determine where to place the object being tested?

Fluid dynamics studies how liquids (hydrodynamics) and gases (aerodynamics) move. It is a sub-discipline of fluid **mechanics**, which studies the forces on fluids.

People who use fluid dynamics in their work come from a very wide range of jobs, including aircraft and rocket design engineers, oil works and plumbers, the local TV meteorologist studying air pressure and wind patterns, and even astronomers who study nebulae in the far reaches of our galaxy. Some of its principles are even used by traffic engineers who design intersections, on— and off— ramps, and roadway as if vehicles are part of a fluid flowing through pipes.

In this activity, we are going to focus on aerodynamics. Aerodynamic problems can be classified according to the flow environment. *External* aerodynamics is the study of flow around solid objects of various shapes. Examples are the **lift** and **drag** on an airplane or a **shock wave** that forms in front of the nose of a rocket. *Internal* aerodynamics is the study of flow through passages in solid objects. Examples are the airflow through a jet engine or an air conditioning pipe.

To understand the motion of air (called flow field) around an object, engineers calculate the forces and moments relating to the object. They need to include different variables (velocity, pressure, density and temperature) of the air to predict how it will behave. Mathematical analysis, empirical approximations, wind tunnel experimentation, and computer simulations are tools that explore the science of heavier-than-air flight.

Engineers use wind tunnels as a tool to research the effects of air moving past solid objects, like rockets, cars, buildings, bicyclists, motorcyclists, etc. An object is placed in the wind tunnel, and then either through a fan or vacuum system, air flows around the object. Smoke or powder is placed in the air stream to observe if there is **turbulent flow** or **laminar flow** past the object. The object is to reduce the amount of turbulent flow, which causes the object to have greater drag.

Engineers also build equipment to test these different concepts. In this lesson, you will construct a wind tunnel. Additionally, you need to test to find the optimum position of the object between the smoke and vacuum.

Colorado State University Extension 4-H programs are available to all without discrimination.

Meet an Engineer!
Travis McGee
Program Manager
Development and Evolution

United Launch Alliance

McGee is responsible for several development projects to enhance the reliability of United Launch Alliance's Atlas V and Delta IV launch systems. United Launch Alliance is the nation's rocket company – designing, producing and launching satellites for NASA, the Department of Defense and commercial companies.

Prior to his program management role, McGee was a lead project engineer responsible for development of flight hardware and a standard integration service to deploy up to six auxiliary spacecraft.

Before joining ULA, McGee was the lead project engineer at Aerojet on a divert-and-attitude control propulsion system for a missile defense interceptor. He led a multidiscipline team from proposal generation through three major design gates and into production.

Travis began his career as an Air Force officer serving one tour at Hill Air Force Base, Utah, managing the second stage of a propulsion replacement program for the Minuteman III missile. His second tour was at Los Angeles Air Force Base, Calif., as a systems engineer on a complex trade study and system architecture of a space based laser concept.

McGee earned his Masters of Science in aerospace engineering from University of Southern California in 2006 and his Bachelor of Science degree in mechanical engineering from Missouri University of Science and Technology in 1995.

McGee has supported and advised this entire series on engineering. Thank you!

Age Appropriate:
4th—HS grades

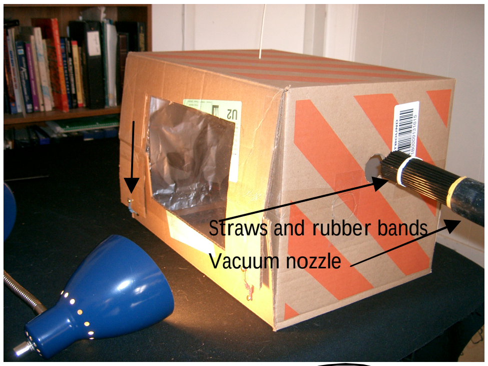
Time Required:
60 minutes

Materials:
- cardboard box~12x12x18"
- black construction paper
- aluminum foil
- folder with transparent cover
- 4 paper fasteners
- 4 rubber bands
- box of cocktail straws
- shipping tape (wider)
- 1/2 or 3/4" tape
- bamboo skewer
- incense and holder
- vacuum cleaner
- matches or lighter
- flashlight or other light
- card stock paper
- box cutter
- scissors
- nail (for punching holes)
- copier or printer

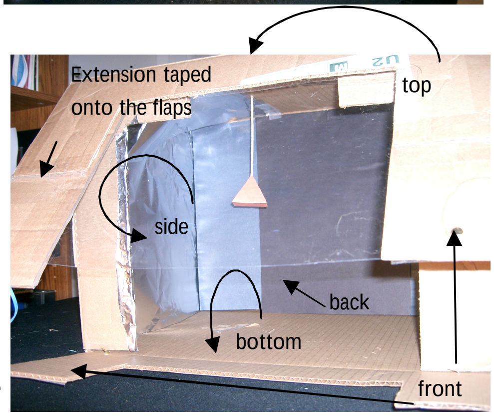
Power Words
- **drag**: the resistance caused by a gas to the motion of a solid object moving through it
- **dynamics**: a branch of mechanics that deals with forces and their relation to the motion of objects
- **fluid**: atoms and molecules in plasma, gas, or liquid phase that easily move and change their relative position
- **laminar flow**: the smooth, orderly movement of a fluid
- **lift:** upward-acting force on an aircraft wing or airfoil
- **mechanics**: a branch of physical science that deals with energy and forces and their effect on objects
- **shock wave**: A sharp change of pressure in a narrow region traveling through a medium, esp. air
- **turbulent flow**: an swirling motion that interrupts the flow of gas or liquid

Experience / "What to Do"

- Using the nozzle of the vacuum cleaner hose, add straws until they are tightly compressed but not flattened when inserted into the nozzle. Hold in place by securing tightly with 2 rubber bands.



- The open end of the cardboard box will become the door/ window of your wind tunnel. All directions are orientated with the open flaps as the front.
- Line the back of the box with black construction paper. Secure with tape.
- Line one side and the top of the box with aluminum foil. Secure with tape.



- Trace the transparent cover on the flaps of the box.
- **DO NOT CUT ON THOSE LINES!** Using the box cutter, cut about 1" **inside those line**, leaving a 1" margin. Note: you need to cut the individual flaps.
- Using some of the cardboard that you just removed from the flaps, cut and tape extensions the same width as the flaps to the upper flaps to lengthen those flaps. This forms the frame for the transparent cover.
- Remove the back of the folder with the transparent cover and discard the back.
- Tape the transparent cover on the upper flaps and the upper flap extensions Do not tape the transparent cover to the lower flap.
- Using a nail, poke a hole into each upper flap extension about 5 inches from the bottom of the box. Using a nail, poke two more holes, one on each of the lower flap about 1" from the bottom of the box.
- Insert 1 paper fastener into each of those holes.
- Tie or otherwise secure one rubber band to each of the lower flap paper fasteners. Each rubber band can be looped over the top flap paper fastener to hold the door closed while conducting wind tunnel experiments. In the first picture, an arrow points to the left side fastener.
- Using the bundled straws, trace the outside dimension of the opening needed to insert the straws into your box onto the side of the box that is not lined with aluminum foil.
- With the box cutter, cut inside that traced outline, making the hole slightly smaller than the straw bundle.
- On the opposite side of the box, align the hole for the vacuum and cut out another hole in the same size. (Why do you need this hole?) Pull the aluminum foil through to the outside of the box and press to smooth.
- The side of the box with aluminum foil is for the incense (necessary for the smoke). The far side is for the vacuum cleaner nozzle with straw bundle.
- Between the two openings on each side, you need to place the object you are testing for aerodynamic design. On the next page is a template for a 3D pyramid. Print that shape onto card stock. Cut out on solid lines, fold on dotted lines, and tape.
- Poke a hole in the top of the box, and insert a bamboo skewer. Insert the tip of the skewer into the pyramid.
- To test the location of your object, you need to use two (<u>2</u>) incense sticks to see the smoke.
- **FIRE SAFETY PRECAUTIONS!** <u>An adult **must** be present. Conduct this outside with water or a fire extinguisher at hand. The entire procedure works better with two people.</u>
- Light the incense and set inside the box. Adjust the object until level and not touching the tips of the incense sticks.
- Carefully close your box flaps and secure with the rubber bands, making sure that the incense holder remains stable.
- Turn on the vacuum cleaner, and place the straw bundle/nozzle near the vacuum cleaner opening.
- Observe the smoke. Adjust the vacuum nozzle/straw bundles until the smoke is drawn across the object. The straw bundle may be near, at, or inside the opening for the best results. See the first picture for completed wind tunnel. Note: you may need to add light or angle window for sunlight.

Share/Reflect/Generalize/Apply: If you were to increase or decrease the hole on the aluminum foil side, how would that change your wind tunnel design? If you were to place the object closer or further from the vacuum side of the wind tunnel, how would that change your design? Do you need to have the box sealed? Why or why not? If you were to use a fan instead of a vacuum cleaner, how would you need to redesign your wind tunnel? If you could find a large enough tube, would that improve your wind tunnel?

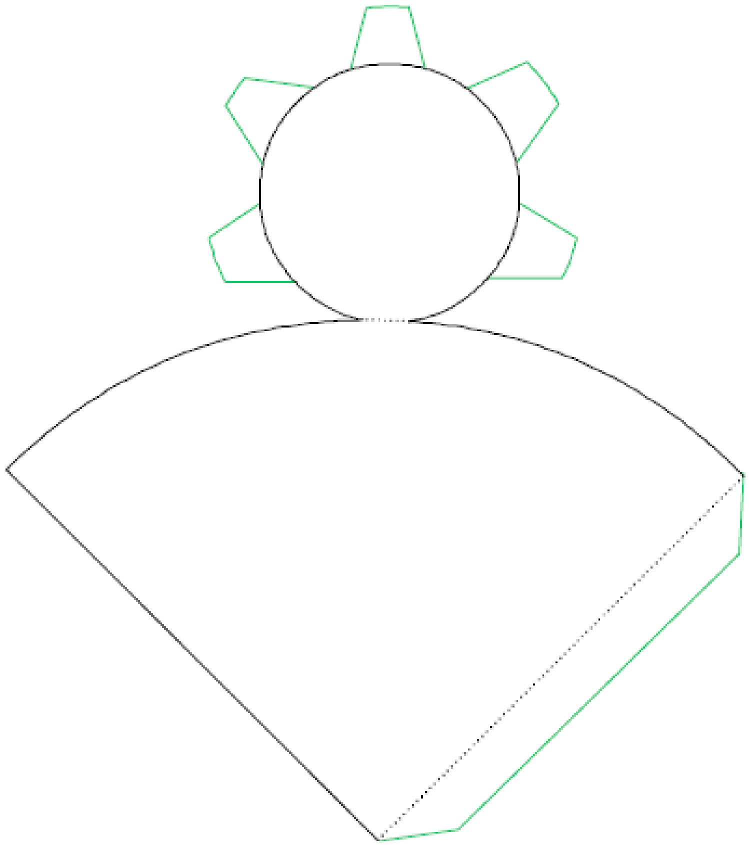
Career Connections: Plumbers, oil workers, mechanical, civil, and aeronautical engineers, pilots, architects, athletes (skiers, bicyclists, motorcyclists especially), rocket scientists, boat captains, kite designers, and any other career that touches fluid mechanics.

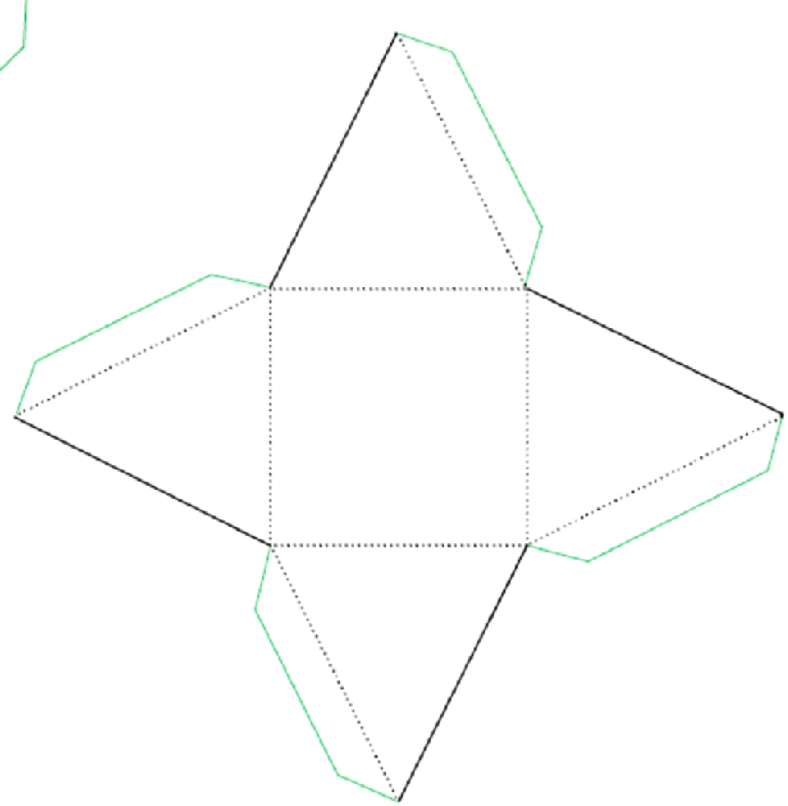
References: Photos: http://www.efluids.com/efluids/gallery/gallery_pages/HW019/text.jsp http://www.bgfl.org/bgfl/custom/resources_ftp/client_ftp/ks2/maths/3d/index.htm; Cutnell, J. D., and Johnson, K. W. (1992) Physics 2nd Edition, John Wiley & Sons, Inc. Pp 1-437; NASA Build Your Own Wind Tunnel captured 11/02/2011 http://www.grc.nasa.gov/WWW/k-12/WindTunnel/build.html ; definitions modified from Merriam Webster online dictionary http://www.merriam-webster.com/.

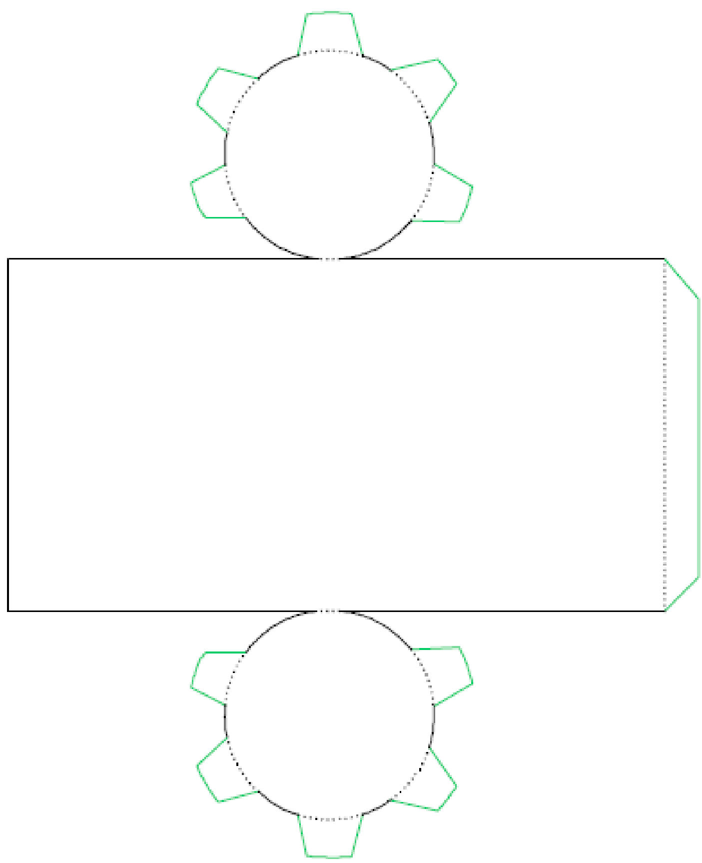
This STEM Connection was developed by: <u>Dr. Barbara J. Shaw</u>. To find out more about 4-H STEM activities, contact your local county Extension office. http://www.ext.colostate.edu/cedirectory/countylist.cfm More activity sheets can be found at http://www.colorado4h.org/k12/activity_sheets/activity.php

Next newsletter, look for the Wind Tunnel Challenge!

Test these shapes in your wind tunnel. Print on cardstock, cut out on solid lines, fold on dotted lines, and tape.
Which shape do you predict will have the least turbulent flow? Why? Record your predictions and reasons for why you think that before testing the designs.







Were you correct? Do you want to modify your reasoning? Keep this record until next month's 4-H newsletter STEM insert for the **Wind Tunnel Challenge! (It just may help you!)**