What a Drag!

Target Grade Levels
Sixth - Twelfth

Time
One class period

Materials (one per student group)
- stop watch or clock with a second hand
- modeling clay (about 24 grams per student group)
- graduated cylinder or other tall tube
- fishing line or other lightweight monofilament line
- counterweight (washer, clay, etc.)
- large box (computer size,
- approximately 1 cubic meter)
- rubber bands
- shapes for testing (Styrofoam works best)
- window (box) fan
- ruler
- knife for cutting cardboard

Knowledge and Skills (TEKS)
- Science:
  - Conduct field and laboratory investigation; and
  - Use scientific inquiry methods to plan and implement investigative procedures including asking questions, formulating testable hypotheses, collecting data, making measurements with precision, organize, analyze, predict trends, and communicate valid conclusions.
- Language Arts:
  - Uses effective listening strategies to provide appropriate feedback in a variety of situations such as informal conversations; formal debates; class discussions; and informative, persuasive, or artistic presentations.

Overview
The purpose of this activity is for students to discover the relationship between the shape of an object and the air resistance (aerodynamics) of that object. Students will then relate their findings to the shapes of automobiles and their resulting fuel efficiency.

Background Information
Drag is the resistance any object feels while moving through the air. If you hold your hand out the window of a moving car, drag is the wind resistance pushing it back. According to the Center for Energy and Environmental Education at the University of Northern Iowa nearly 60% of the fuel a car uses to drive at a constant 55 mph goes into overcoming wind resistance. So reducing a car's drag can greatly improve its gas mileage (miles per gallon).

The "Cd" or Coefficient of drag, measures how well a shape cuts the wind. It can be calculated for any object from a brick to a blimp. The lower the Cd, the more aerodynamic the shape. For cars and trucks, a low Cd translates directly into better gas mileage. A drop in the average Cd of all road vehicles in the U.S. from 0.4 to 0.3 could reduce the nation's gasoline consumption by 10 percent. This would add up to a yearly savings of over 10 billion gallons of gasoline.

Many students may not realize it, but air is a fluid. A fluid can be a liquid or a gas. It is typically considered anything that can flow and which responds to changes in pressure. Because of its fluid properties, water can be used to illustrate the amount of drag objects have when passing through a fluid. An object that has low drag when moving through air will also have a low drag when it is moved through water. Keep reminding students of this as they are collecting their drag data using water.

Procedure

1) Vocabulary
   a) aerodynamics
   b) drag
   c) coefficient of drag (Cd)
   d) fluid
   e) cube
   f) cone
   g) parachute
   h) airfoil
   i) sphere
2) Activities
   a) The fuel efficiency of cars would be greatly increased if air resistance could be reduced. Many students have likely held their hand out the car window while riding. You can feel your hand getting pushed back. This is largely the result of air resistance.
   b) The greater the air resistance, the more fuel it takes to move a car. Race cars are built with sleek designs to allow them to go faster on less fuel, but these cars lack extra room inside. They are not designed to carry passengers or other items. The challenge is to discover the relationship between the shape of an object and its speed through a fluid. To discover this the speed of objects will be measured through water, since it is easier to notice differences in speed through a liquid than it is through a mixture of gases like air. Be sure students realize that their findings in water will be analogous to what would happen to the object's speed as it travels through air. Air is considered a fluid. Be sure to communicate this to students. Present students with this challenge: How does the shape of an object affect its speed through water?
      i) Ask students to brainstorm possible shapes to test. Most students will likely name shapes such as a cone, a square, a sphere, an oval, a wedge and a torpedo. Ask students to predict which shapes will fall fastest through the water. Rather than explaining the lab set-up to students, it may be easier to demonstrate the technique, do so by:
         (1) Creating a shape out of clay.
         (2) Push one end of a piece of fishing line through the shape, securing it with a knot.
         (3) Show students how fast the shape drops through the water when it is dropped into a large graduated cylinder filled with water.
         (4) Now attach a counter weight to the other end of the string.
         (5) This will serve to slow down the clay as it drops through the water.
         (6) Ask students if they think this is a fair test of how fast the clay drops.
         (7) Hopefully students will realize that it is okay to use the counterweight as long as it is used for every trial.
         (8) Likewise, when the shape of the clay is altered, the same clay lump should still be used.

(9) This will ensure that the shape, not the mass, is the only factor being varied in this experiment.

ii) Using a stopwatch, record the time it takes for the object to fall through the water. Continue testing until three consistent trials have occurred. Ask students to devise their own data tables for recording their data.

iii) Before allowing students to investigate different shapes on their own, ask students how they can best control as many variables as possible in their experiment. Some suggestions might include always using the same line, drying off the line after each trial, always using the same lump of clay, performing several trials for each shape, and having the same person run the timer each trial and the same person release the clay each time.

iv) Once students have collected their own data, have students answer the Summing Up questions.

3) Review
Have students go home and search through the magazines their family has to find pictures of different vehicles. Each student must bring in a picture of a vehicle, along with that vehicle's descriptive statistics (make, model, production year, weight, number of passengers, and EPA rated fuel efficiency) and present to the class their vehicle and their ideas on why the vehicle gets the fuel efficiency it gets.Many automakers list the coefficient of drag under each car's specifications. Look for these figures and make a comparison between the Cd value, fuel efficiency, shape, and size of the car. Report your findings back to the class. Some students might want to prepare a bulletin board display containing pictures of various cars and their Cd values. Perhaps the bulletin board could be designed as a guessing game, where those looking at the board had to guess which cars had the lowest drag and which had the highest drag values.

4) Evaluation

a) Summing Up Questions

i) Which shapes had the least amount of drag and which had the most drag?

ii) Explain how the aerodynamics of a car relates to its fuel efficiency?

b) Sample Answers to Summing Up Questions

i) Students should find the shapes to fall from fastest to slowest in this order: torpedo, cone, wedge, sphere, and cube.

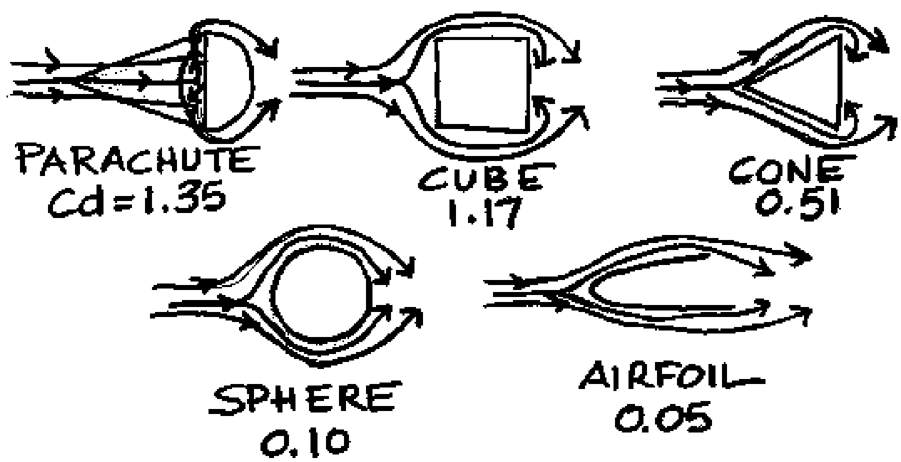
ii) The more aerodynamic the vehicle, the less gasoline it takes to move the vehicle.

c) Discuss results of experiment and answers to Summing Up Questions.

5) Extension

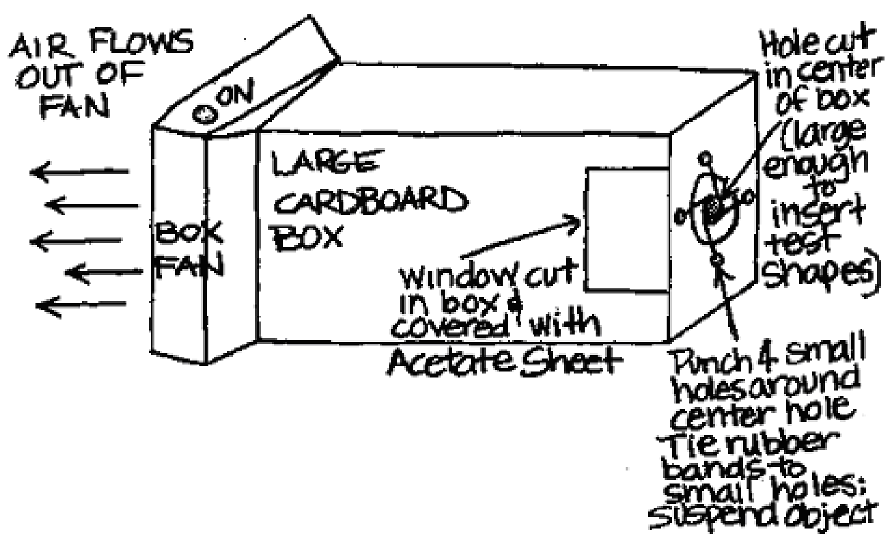
a) Challenge students to draw lines to represent the air current passing over each of the objects shown below. Rate the objects from the one with the largest drag to the object with the least drag.

b) Here are the actual findings



c) Some students might enjoy testing resistance in a homemade wind tunnel.

i) The drawing below illustrates how to prepare the wind tunnel.



ii) To test different shapes, turn on the fan. Looking through the window in the box, measure how far the object moves into the box when the fan is turned on. You will be surprised how well this simple design works. Students will need to make certain that the mass of their test objects is about the same. Remind them to control as many variables as possible.

Adapted from: “Activity 14 - Smog” *United States Environmental Protection Agency–Project A.I.R.E.* 2003. Page 141.