Junior Solar Sprint – The Body

Key Words:
- aerodynamics
- chassis
- drag
- turbulence
- vehicle body

Student Objective

The student:
- given a design will be able to predict whether the aerodynamic drag will increase or decrease as variables in the frontal area and body shape are manipulated
- can explain the use of a wind tunnel to assist in aerodynamic design

Time:
1 - 1.5 hours for investigation

Materials:
- miniature or toy car (1 per group). Note: teams may use their JSS chassis/wheel assembly if they can disconnect the motor and any gearing so that it is free rolling
- 6 x 8" piece of foamcore or thin plywood (1 per group)
- masking tape
- ramp
- empty soda can (1 per group)
- heavy paper
- (2) dowels, 10" long, ½" in diameter or greater (2 per group)
- Various materials such as heavy paper, aluminum foil, shirt cardboard, thin foam, mylar, plastic sheeting, and recycled materials such as plastic soda bottles, disposable containers, and food packaging items
- 6" strips of lightweight string or yarn
- box fan
- cardboard box with a face dimension close to that of the fan
- cardboard tubes (paper towel size)

Procedure (prior to class time)

1. Remove two opposite sides from the cardboard box and fill it with cardboard tubes so that air blown in one side must pass through the tubes to flow out the other side. This is to help funnel the air from the fan in one straight direction to simulate an air tunnel.

Procedure

1. Students should work in their Sprint teams (2 - 4 students).
2. Lead a classroom review of aerodynamics. Remember that aerodynamics also applies to boats and other objects in water, as well as birds, fish, penguins, etc. Some of the students may wish to discuss current commercial and race car body designs.
3. Have a box of various body materials available so that students can pick their own investigation materials.
4. Pass out the materials that all the groups will be using.
5. Students should complete the exercises in the Researcher's Portfolio.
6. Give the teams time to discuss how they plan to use these findings in their vehicle design.
7. Students should continue working on their Sprint vehicles.

Internet Sites:

http://www.uh.edu/engines/engines.htm

University of Houston's College of Engineering's *Engines of Our Ingenuity* series, #255 "Car Design" (**http://www.uh.edu/engines/epi255.htm**), and #1520 "Automobile Drag Coefficients" (**http://www.uh.edu/engines/epi1520.htm**). These are transcripts from John Lienhard's popular radio show. Audio versions are also available on the website.

Junior Solar Sprint III – The Body

			.1	.2	.3	.4	.5	.6	.7
Nature of Matter	Standard 1	SC.A.1.3-		X					
	Standard 2	SC.A.2.3-							
Force and Motion	Standard 1	SC.C.1.3-	X						
	Standard 2	SC.C.2.3-		X	X		X	X	
Nature of Science	Standard 1	SC.H.1.3-					X		
	Standard 2	SC.H.2.3-							
	Standard 3	SC.H.3.3-							
Math Standards:	MA.B.4.3.1, and MA.B.4.3.2								

Benchmark MA.B.4.3.1: The student selects appropriate units of measurement and determines and applies significant digits in a real-world context.

Grade Level Expectations

The student:

Sixth

- selects the appropriate unit of measure for a given real-world situation
- knows the approximate nature of measurement and measures to the specified degree of accuracy

Seventh

- selects appropriate units of measurement in a real-world context
- knows that measurements are always approximate and that the degree of accuracy of a measurement depends upon the precision of the instrument
- determines the appropriate precision unit for a given situation

Eighth

- selects the appropriate unit of measure for a given situation
- determines the appropriate precision unit for a given situation.

Benchmark MA.B.4.3.2: The student selects and uses appropriate instruments, technology, and techniques to measure quantities in order to achieve specified degrees of accuracy in a problem situation.

Grade Level Expectations

The student:

Sixth

- selects an appropriate measurement tool

- determines the interval of a scale and reads the scales on a variety of measuring instruments
- measures accurately with the measurement tools

Seventh
- selects a measurement tool appropriate to a given situation
- measures accurately with the measurement tools to the specified degree of accuracy for the task and in keeping with the precision of the measurement tool

Eighth
- selects and uses appropriate instruments, technology, and techniques to measure quantities and dimensions to a specified degree of accuracy.

Benchmark SC.A.1.3.2: The student understands the difference between weight and mass.
Grade Level Expectations
The student:
Seventh
- understands that weight is the result of gravitational pull on an object.

Benchmark SC.C.1.3.1: The student knows that the motion of an object can be described by its position, direction of motion, and speed.
Grade Level Expectations
The student:
Sixth
- knows that a change in motion and position can be measured

Seventh
- knows that the motion of an object can be described by its position, direction of motion, and speed

Eighth
- knows that speed, velocity, and acceleration can be calculated, estimated, and defined.

Benchmark SC.C.2.3.2: The student knows common contact forces.
Grade Level Expectations
The student:
Eighth
- knows some common contact forces (for example friction, traction, tension).

Benchmark SC.C.2.3.3: The student knows that if more than one force acts on an object, then the forces can reinforce or cancel each other, depending on their direction and magnitude.
Grade Level Expectations
The student:
Sixth
- recognizes the result of several forces acting on an object
- knows that the net force is dependent on the direction and magnitude of forces acting on a body

Eighth
- recognizes the forces that act on a given object

- knows that the overall effect of a force can be predicted.

Benchmark SC.C.2.3.5: The student understands that an object in motion will continue at a constant speed and in a straight line until acted upon by a force and that an object at rest will remain at rest until acted upon by a force.

Grade Level Expectations

The student:

Eighth

- knows ways in which a net force can act on an object (for example slowing down an object traveling in the direction opposite of the net force).

Benchmark SC.C.2.3.6: The student explains and shows the ways in which a net force (that is, the sum of all acting forces) can act on an object (e.g., speeding up an object traveling in the same direction as the net force, slowing down an object traveling in the direction opposite of the net force).

Grade Level Expectations

The student:

Eighth

- knows ways in which a net force can act on an object.

Benchmark SC.H.1.3.5: The student knows that a change in one or more variables may alter the outcome of an investigation.

Grade Level Expectations

The student:

Sixth

- understands the importance of the control in an experiment
- knows how to identify the independent and dependent variables in an experiment
- uses appropriate experimental design, with consideration for rules, time, and materials required to solve a problem

Seventh

- extends and refines knowledge of how to identify the independent and dependent variables in an experiment
- extends and refines use of appropriate experimental design, with consideration for rules, time, and materials required to solve a problem
- uses rules, time, and materials in ways that ensure the identification and separation of variables in an experiment to solve a problem

Eighth

- extends and refines knowledge of how to identify the independent and dependent variables in an experiment
- extends and refines use of appropriate experimental design, with consideration for rules, time, and materials required to solve a problem
- extends and refines use of rules, time, and materials in ways that ensure the identification and separation of variables in an experiment to solve a problem.

Junior Solar Sprint – The Body

aerodynamics - the study of air flow and its effect on moving objects.

chassis - the component that must provide structural support for the motor, wheels, axles, etc.

drag - the retarding force (friction) acting on a body moving through a fluid (such as water or air)

turbulence - the flow of a fluid (such as water or air) that varies in direction or magnitude.

vehicle body - the outer skin of a vehicle that provides protection for the occupants as well as increasing performance through the reduction of aerodynamic drag.

Junior Solar Sprint – The Body

The body of your family automobile has several purposes. It protects the passengers from the weather, provides safety in the event of a crash, and it adds to the way the car looks. But it also improves the way the car performs because a well designed body can reduce the force of the air as the car moves through it. This force, the force that the air exerts on the vehicle as it moves through it, is called aerodynamic drag or 'wind resistance'.

Part 1 - Vehicle Size and Shape
There are two primary physical characteristics responsible for aerodynamic drag on a vehicle moving forward–the frontal area of the vehicle, and how streamlined the vehicle is.

1. Using a ramp and a toy car (or your JSS vehicle with the motor and gears disconnected so that it is free rolling), release the car from the top of the ramp several times until you can observe where the car repeatedly stops. Mark this distance with a piece of masking tape. Measure the distance and enter it in the chart below.

   Attach a 6 x 8" piece of foamcore or plywood with masking tape to the top of the car in the orientations listed below. In tests #2 and #3 the panel should be extending straight up from the top of the car. Run each test several times to observe where the car repeatedly stops. Mark this distance and add it to the chart below.

Test #	Orientation of board	Distance Traveled
1	No panel attached	
2	Panel perpendicular to the direction traveled (crosswise on vehicle, standing straight up)	
3	Panel parallel to the direction traveled (lengthwise on vehicle, standing straight up)	
4	Panel laying flat on the top of the vehicle (0^{o} angle)	
5	Panel slanted back at a 30^{o} angle	

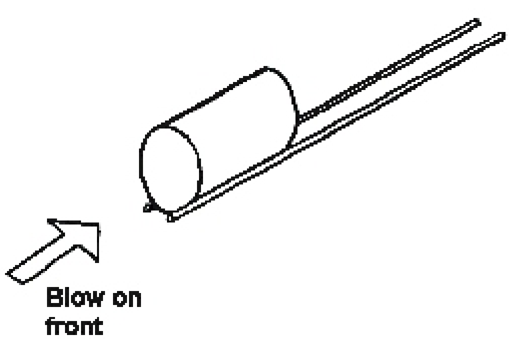
2. Did the car have less aerodynamic drag in test #2 or test #3?

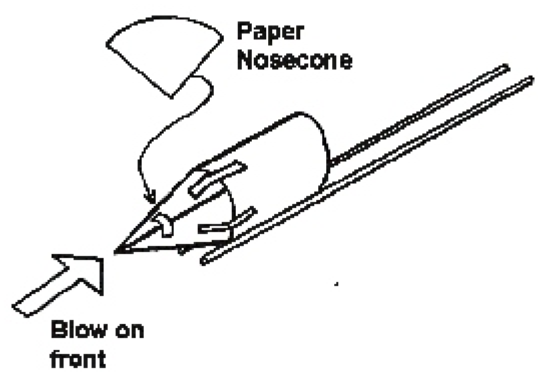
3. Tests #4 and #5 could be used to simulate possible ways to attach your PV panel to your car. Did the car have less aerodynamic drag in test #4 or test #5?

4. In which test did the results come closest to test #1, where there was not any additional drag?

5. Why do you think this is so?

Place an empty soda can on two dowels, as in the diagram on the left below, so that it rests on the dowels instead of the table. Blow on the can to see how easy or hard it is to make it move.





6. Make a nosecone for the can and attach it with tape. Place the can back on the dowels and blow on it. Is it easier or harder to move the can?

7. Why do you think this is so?

8. Which design would have the least aerodynamic drag if you were to use it for the front of your vehicle?

Part 2 - Wind Tunnel Testing

Wind tunnels are used frequently in the design process for automobiles, airplanes, rockets, and even bicycles. Wind tunnel experiments show which areas of the vehicle body have a streamlined efficient design, and which areas have turbulence–an increase in the amount of aerodynamic drag.

A simulated wind tunnel can be made with a box fan and a cardboard box filled with tubes to help funnel the wind in one streamlined direction. Position a platform that is large enough to hold your vehicle near the center of the box where the air will be coming out.

9. Using heavy paper, aluminum foil, shirt cardboard, thin foam, mylar, plastic sheeting, or any recycled material that you wish, construct a prototype body for your chassis. (Note: this body is for this investigation only–it does not have to be your finished design!) Sketch your prototype body below.

10. Attach strings in several places on the front of your vehicle, and also one on each side just back of the front wheels and three along the back edge of your vehicle. Place your vehicle on the platform and turn the fan on high. Observe the string. In an efficient design, the strings will float straight along the surface of the car. In a less effective design, they will flap. Describe below what you observed.

11. How would you modify your prototype to make it more aerodynamic?

Discussion and Design

With your group, discuss how you might use the findings from your investigation to help you design your Sprint vehicle. As before, remember there are a lot of variables to consider. The challenge from this investigation is to decide what type of body material and shape you want for your vehicle. As you plan, here are some things to consider:

- To be in compliance with the rules, your vehicle must have a closed body (no open wire frames) with sides large enough for a 3 centimeter square decal.
- Aerodynamic drag occurs on the underside of your vehicle also!
- Most things that move through the air use smooth, 'slick' body surfaces. This is because smooth surfaces will slip through the air, causing less turbulence, than rough surfaces
- Tilting your photovoltaic panel to maximize its power output has a tradeoff. Although you will increase the power output of your panel, it will increase the vehicle's aerodynamic drag.
- Think lightweight! If attached smoothly, thin materials such as paper or cellophane can be an effective body.