Junior Solar Sprint – The Body

Student Objectives
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

Key Words:
aerodynamics
chassis
drag
turbulence
vehicle body

Time:
1 – 1½ 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 act as 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 vehicles 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 Science Journal.
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.

Tips for Success

- The body for the JSS cars can be simple–paper, shirt cardboard, a plastic bottle, foamboard, etc. The students should try to think as lightweight as possible.
- A full body is not required for Junior Solar Sprint cars. They are required to have a space big enough for the decals on the side. That being said, there is an advantage to making the vehicle aerodynamic–at least to the point that head-on and cross winds on race day will not hinder the performance of the vehicle.

Key Words & Definitions

- **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

Related Reading

- ***Car Science***, by Richard Hammond (DK Children, 2008)
  This book is a "how it works" guide to modern cars with exploded diagrams, cutaways, key physics concepts and a look into the future of cars.
- ***DK Eyewitness Books: Car***, by Richard Sutton (Dk Eyewitness Books, 2005)
  A photographic history of the car.

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

Florida NGSS Standards & Related Subject Common Core

			.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	.11	.12
Grade 6														
Practice of Science	# 1	SC.6.N.1	X			X	X							
Theories, Laws, Hypothesis, Models	# 3	SC.6.N.3				X								
Motion of Objects	# 12	SC.6.P.12	X											
Forces & Changes in Motion	# 13	SC.6.P.13	X											
Grade 7														
Practice of Science	# 1	SC.7.N.1	X											
Energy Transfer & Transformations	# 11	SC.7.P.11		X										
Grade 8														
Practice of Science	# 1	SC.8.N.1	X	X				X						
Role of Theories, Laws, Hypotheses, and Models	# 3	SC.8.N.3	X											

Sixth Grade Benchmarks
Science--Big Idea 1: The Practice of Science

- SC.6.N.1.1 - Define a problem from the sixth grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.
- SC.6.N.1.4 - Discuss, compare, and negotiate methods used, results obtained, and explanations among groups of students conduction the same investigation.
- SC.6.N.1.5 - Recognize that science involves creativity, not just in designing experiments, but also in creating explanations that fit evidence.

Science–Big Idea 3: The Role of Theories, Laws, Hypothesis and Models

- SC.6.N.3.4 - Identify the role of models in the context of the sixth grade science benchmarks.

Science–Big Idea 12: Motion of Objects

- SC.6.P.12.1 - Measure and graph distance versus time for an object moving at a constant speed. Interpret this relationship.

Science–Big Idea 13: Forces and Changes in Motion

- SC.6.P.13.1 - Investigate and describe types of forces including contact forces and forces acting at a distance, such as electrical, magnetic and gravitational.

Seventh Grade Benchmarks

Science--Big Idea 1: The Practice of Science

- SC.7.N.1.1 - Define a problem from the seventh grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.

Science–Big Idea 11: Energy Transfer and Transformations

- SC.7.P.11.2 - Investigate and describe the transformation of energy from one form to another.

Eighth Grade Benchmarks

Science--Big Idea 1: The Practice of Science

- SC.8.N.1.1 - Define a problem from the eighth grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.
- SC.8.N.1.2 - Design and conduct a study using repeated trails and replication.
- SC.8.N.1.6 - Understand that scientific investigations involve the collection of relevant empirical evidence, the use of logical reasoning, and the application of imagination in devising hypotheses, predictions, explanations and models to make sense of the collected evidence.

Science–Big Idea 3: The Role of Theories, Laws, Hypotheses, and Models

- SC.8.N.3.1 - Select models useful in relating the results of their own investigations.

National Next Generation Science Standards - Sixth to Eighth Grade Standards

Science–Engineering Design

- MS-ETS1-1 - Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 - Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- MS-ETS1-3 - Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- MS-ETS1-4 - Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

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	

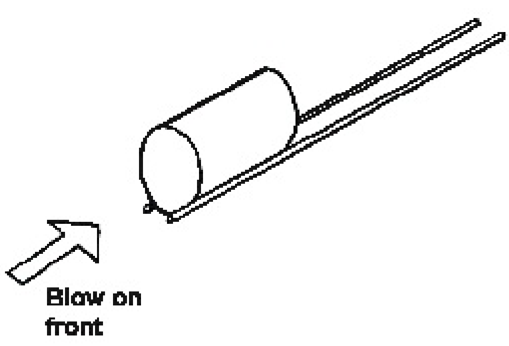
2. Did the car have less aerodynamic drag in test #2 or test #3?

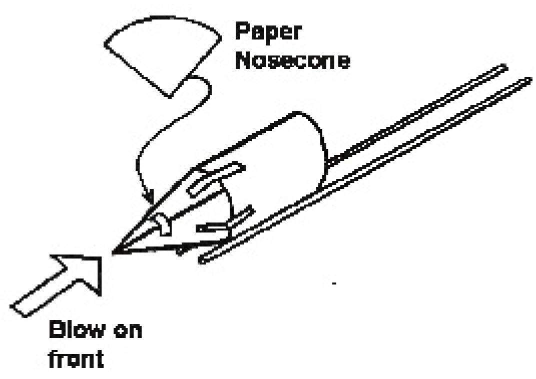
3. Tests #4 and #5 could be used to simulate possible ways to attach your PV panel to your car. Did the car have less aerodynamic drag in test #4 or test #5?

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 nose cone 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 side 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. What could you do to make the surface of your vehicle more "slick"?
- 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.