Junior Solar Sprint – The Photovoltaic Panel

Student Objectives
The student:
- will make engineering design decisions based on their knowledge of the physics of photovoltaics
- will explain how shadows, the angle of the panel, reflectors and temperature affect the electrical output of the photovoltaic panel

Key Words:
amp
current output
electricity
efficiency
multimeter
orientation
photovoltaic
volt
watt

Materials:
- Junior Solar Sprint team journal

Time:
1 hour for discussion and planning

Procedure
1. Students should have previously completed *The Photovoltaic Panel* activity. If not, have the teams complete the activity using their Junior Solar Sprint panel.
2. Lead a classroom review of photovoltaics and basic electricity.
3. Discuss with students their previous findings in *The Photovoltaic Panel* activity.
4. Give the teams time to discuss how they plan to use these findings in their vehicle design.
5. Teams should sketch their ideas in their Design Notebooks.

Tips For Success
- Reflectors will increase the electrical output of the panel, but can shade the panel when the Sun is low in the sky and reflectors are not effective in windy conditions.
- Photovoltaics produce the most electricity during the hours of peak sunshine, approximately 10:00 - 2:00 each day.
- Haze or shade will decrease the output of the panel, however the best cars will still be able to run in hazy conditions.
- To test the panels when sunlight is not available, use an overhead projector, xenon light or a halogen light. If you use a halogen bulb, care must be taken with the extreme heat from the bulb–it will damage the panel and can burn the skin.
- Velcro may be used to secure the panel to the chassis/body of the car, so that the panel can be used with several vehicles or for several years. Solder alligator clips on the leads from the panel so it can be attached to the motor easily.
- If students use rubber bands or tie-wraps to secure the panel to the car, it can shade part of

the panel and decrease its output.

Key Words & Definitions

- **amp –** unit of measure of the number of electrons flowing through a wire per unit of time (current)
- **angle of incidence** – the angle of the sun in relation to level ground, it varies according to location (latitude) and time of day
- **current output** – the number of amps flowing through the circuit at a particular time
- **electricity** – general term for the type of energy concerned with the flow of electrons
- **efficiency** – the degree to which a system produces the desired effect without waste. In energy, it is used to describe the amount of available energy source that is turned into energy that we can use; for example the percentage of sunlight that is turned into electricity.
- **multimeter –** an instrument to measure electrical output in amps and volts and resistance in ohms
- **orientation** – position in relation to the points of the compass and elevation angle
- **photovoltaic –** the effect of producing electric current using light
- **volt** - the unit of measure of the force of electricity in a circuit. The volt is not a unit of flow, it is analogous to pressure of water in a hose.
- **watt** – the standard unit used to measure electricity, specifically the rate at which electrical energy is dissipated. The watt is the equivalent of one joule per second. Amperage and voltage are multiplied to obtain the wattage.

Related Reading

- ***Solar Energy Projects for the Evil Genius*** by Gavin Harper (McGraw-Hill, 2007)
  This book includes more than 50 solar energy projects with plans, diagrams and schematics.

Internet Sites

http://www.chuck-wright.com/SolarSprintPV/SolarSprintPV.html
Explains the basic physics of the Junior Solar Sprint photovoltaic panel including graphs of panel current and output power in varying conditions.

https://www.fsec.ucf.edu/go/solar_basics/
Florida Solar Energy Center's photovoltaic fundamentals page explains the basics of photovoltaic cells including their manufacture, the components of systems, as well as the pros and cons of photovoltaic power. Site is suitable for teachers, mentors and advanced students.

http://www.engineeringtoolbox.com/electrical-formulas-d_455.html
Common electrical formulas.

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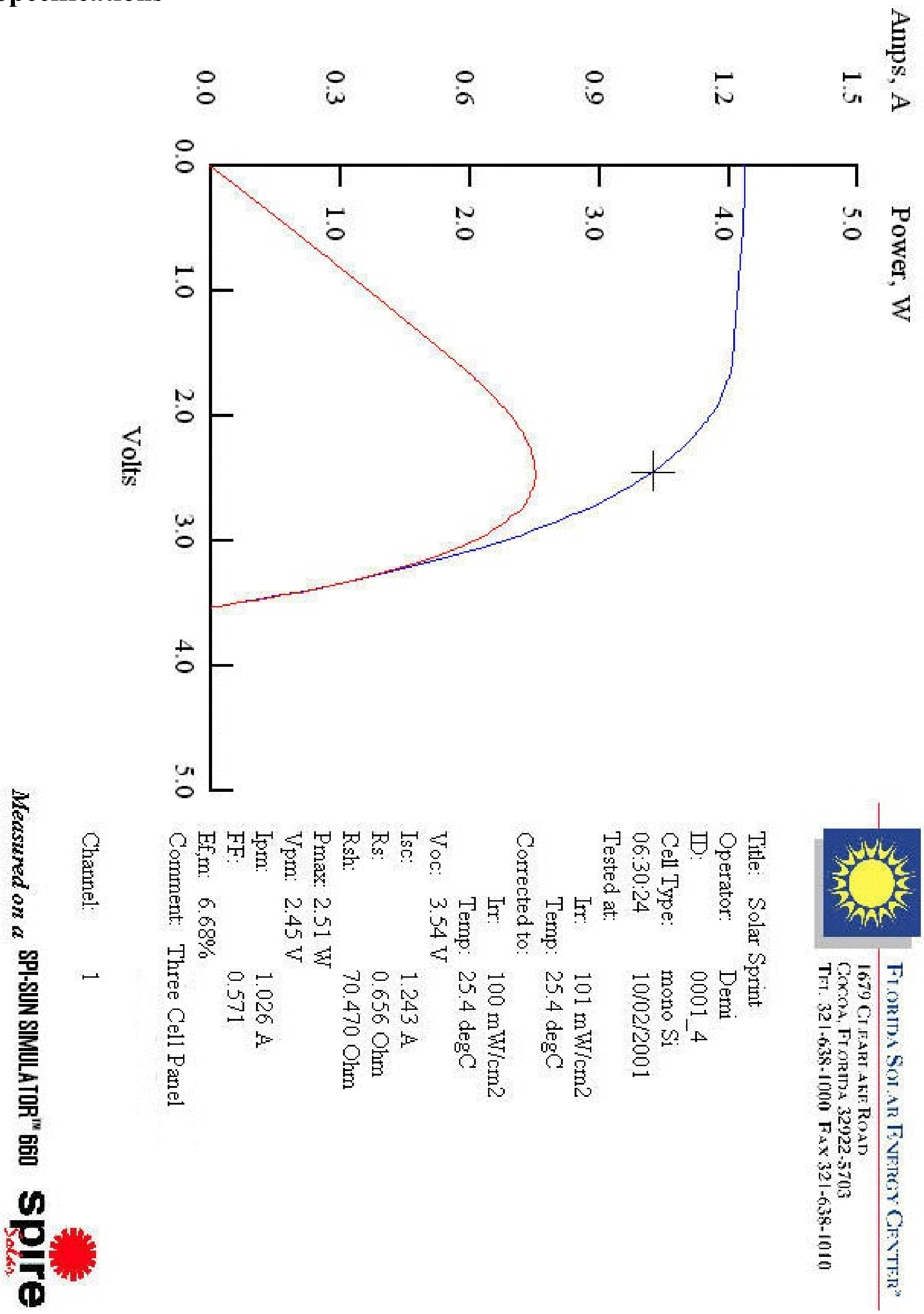
Panel Specifications



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Note: Standards listed are for this activity plus the related activity *The Photovoltaic Panel*.

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**							
Grade 7														
Practice of Science	**# 1**	**SC.7.N.1**	**X**											
Forms of Energy	**# 10**	**SC.7.P.10**	**X**											
Energy Transfer & Transformations	**# 11**	**SC.7.P.11**		**X**										
Grade 8														
Practice of Science	**# 1**	**SC.8.N.1**	**X**	**X**				**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.

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 10: Forms of Energy

- SC.7.P.10.1 - Illustrate that the Sun's energy arrives as radiation with a wide range of wavelengths, including infrared, visible, and ultraviolet, and that white light is made up of a spectrum of many different colors.

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.

National Next Generation Science Standards - Sixth to Eighth Grade Standards

Science–Motion and Stability: Forces and Interactions

- MS-PS2-3 - Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

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.

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Discussion and Design Decisions
With your group, discuss how you might use the findings from *The Photovoltaic Panel* investigation to help you design your Sprint vehicle. Remember, there are a lot of variables in the design of your vehicle. Each team will approach the design of their vehicles differently, with the final outcome not known until the day of the race. Your challenge is to obtain the most power you can without adding negative factors that outweigh the advantages. Here are some points to consider:

- Having the panel facing directly at the Sun will increase its energy output. But how do you use that knowledge to help you design your vehicle? The position of the Sun during the race is unknown until the day of the race. A solar panel that can be tilted would allow you to adjust the panel on your car the day of the race, but at what cost? A ‘tiltable’ solar panel may weigh more and cause more aerodynamic drag, slowing your car down. Is the increased power output that you may get from an adjustable tilt panel worth the drawbacks?
- A reflector could significantly increase the amount of sunlight striking your panel. However, just as with an adjustable tilt panel, a reflector will add weight and cause more aerodynamic drag. The amount of wind on race day is unknown and could have a significant effect on your vehicle. Strong crosswinds have been know to flip over vehicles during a race. Also, what effect will reflectors have on the temperature of the panel? Commercial installations of photovoltaics seldom use reflectors because the increase in temperature lowers the efficiency of the cells. Is the increased power output that you get from reflectors on the car worth the drawbacks?
- An easy, versatile way to attach your panel to your car is with velcro. This allows you to remove and reinstall your panel easily, and can also let several teams use the same panel.
- Attach alligator clips to the power leads from the panel as a convenient and fast way to disconnect the panel.
- How could you use the knowledge that heat negatively affects photovoltaics to help you increase the output of the panel on the day of the race?

Sketch several ideas in your Design Notebook. Decide as a team which idea to try first and how you will test your idea.