# Junior Solar Sprint – The Photovoltaic Panel

**Student Objective**
The student:
- given basic photovoltaic panel installation design scenarios will be able to predict how the panels will function as variables (i.e. panel angle, shadows) are changed.
- will be able to explain how shadows, the angle of the panel, reflectors and temperature affect the electrical output of the photovoltaic panel
- will be able to determine the angle of incidence of the sun

**Key Words:**
amp
angle of incidence
current output
electricity
efficiency
multimeter
orientation
photovoltaic
volt
watt

**Materials**
- Junior Solar Sprint panel
- Multimeter
- Protractor
- Ice
- Aluminum (foil or disposable baking pans), or other reflective material
- Junior Solar Sprint team journal

**Time:**
1 - 1.5 hours for investigation

**Procedure**
1. Students should work in their Sprint teams (2 - 4 students).
2. Lead a classroom review of photovoltaics and basic electricity.
3. Discuss with students their previous findings in the Solar Powered Systems activity. Have the students hypothesize what their results will be using the Sprint panel which is larger than what they used in previous experiments.
4. Give each team their Junior Solar Sprint panel, a multimeter and a protractor. Remind the students that their panels are fragile and can be broken if bent.
5. Students should complete the exercises in their Science Journal.
6. Give the teams time to discuss how they plan to use these findings in their vehicle design.
7. Teams should sketch their ideas in their team journals.

**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

**http://www.fsec.ucf.edu/en/consumer/solar_electricity/basics/index.htm**

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.outlawnet.com/~oclass/electricity/formulas.htm**

Common electrical formulas.

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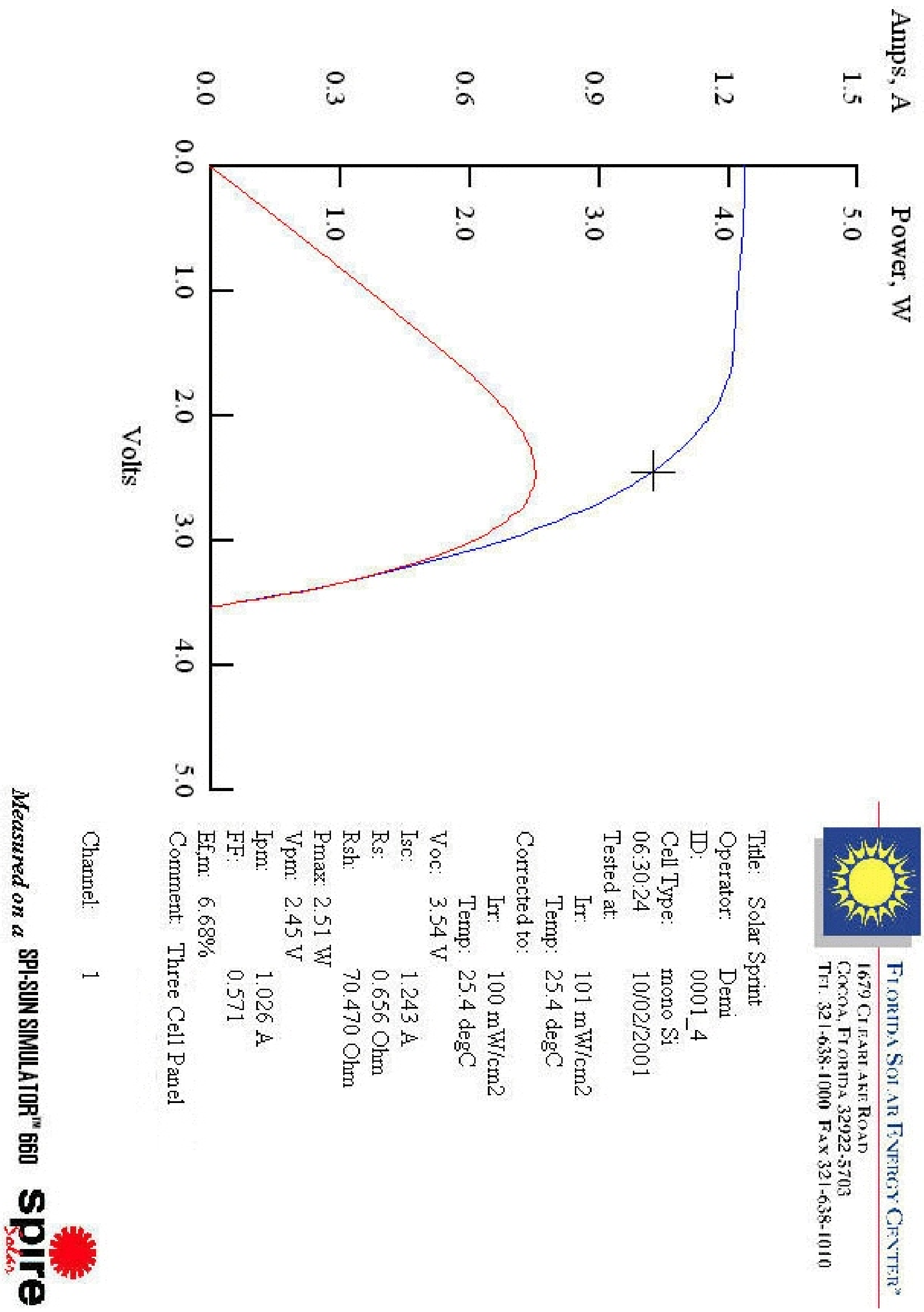
**Panel Specifications**



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| | | | .1 | .2 | .3 | .4 | .5 | .6 | .7 |
|---|---|---|---|---|---|---|---|---|---|
| Nature of Matter | Standard 1 | SC.A.1.3- | | | | | | | |
| | Standard 2 | SC.A.2.3- | | | X | | | | |
| Energy | Standard 1 | SC.B.1.3- | X | X | X | X | | | |
| | Standard 2 | SC.B.2.3- | X | | | | | | |
| Nature of Science | Standard 1 | SC.H.1.3- | | | | | X | | |
| | Standard 2 | SC.H.2.3- | | | | | | | |
| | Standard 3 | SC.H.3.3- | | | | | | | |
| Math Benchmarks: | MA.B.1.3.2, MA.B.4.3.1, and MA.B.4.3.2 | | | | | | | | |

**Benchmark MA.B.1.3.2:** The student uses concrete and graphic models to derive formulas for finding rates, distance, time and angle measures.

**Grade Level Expectations**

The student:

*Sixth*

- identifies a protractor as a tool for measuring angles and measures angles using a protractor

*Seventh*

- finds the measure of an angle by measuring with a protractor or applying angle relationships.

**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.2.3.3:** The student knows that radiation, light and heat are forms of energy used to cook food, treat diseases and provide energy.

**Grade Level Expectations**

The student:

*Sixth*

knows forms of radiant energy and their applications to everyday life

*Seventh*

knows uses of radiation, light and thermal energy to improve the quality of life for human beings

*Eighth*

extends and refines knowledge of uses of forms of energy to improve the quality of life.

**Benchmark SC.B.1.3.1**: The student identifies forms of energy and explains that they can be measured and compared.

**Grade Level Expectations**

The student:

*Sixth*

- knows different types of energy and the units used to quantify the energy
- understands that energy can be converted from one form to another

*Eighth*

- knows examples of natural and man-made systems in which energy is transferred from one form to another.

**Benchmark SC.B.1.3.2:** The student knows that energy cannot be created or destroyed, but only changed from one form to another.
**Grade Level Expectations**
The student:
*Sixth*
- understands that energy can be changed in form
- uses examples to demonstrate common energy transformation.

**Benchmark SC.B.1.3.3:** The student knows the various forms in which energy comes to Earth from the Sun.
**Grade Level Expectations**
The student:
*Sixth*
- knows types of radiant energy that come to Earth from the Sun
- knows the effect of sunlight on photosynthetic pigments

*Seventh*
- knows the characteristics, effects, and common uses of ultraviolet, visible and infrared light

*Eighth*
- knows ways to measure the various forms of energy that come from the Sun.

**Benchmark SC.B.1.3.4:** The student knows that energy conversions are never 100% efficient.
**Grade Level Expectations**
The student:
*Seventh*
- knows that useful energy is lost as heat energy in every energy conversion

*Eighth*
- knows that energy conversions are never 100% efficient and that some energy is transformed to heat and is unavailable for further useful work.

**Benchmark SC.B.2.3.1:** The student knows that most events in the universe (e.g. weather changes, moving cars, and the transfer of a nervous impulse in the human body) involve some form of energy transfer and that these changes almost always increase the total disorder of the system and its surroundings, reducing the amount of useful energy.
**Grade Level Expectations**
The student:
*Sixth*
- understands that energy moves through systems

*Seventh*
- knows that as the amount of useful energy of a system decreases, the total disorder in the system increases

*Eighth*
- knows that energy transfer is not efficient.

**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 Photovoltaic Panel

**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. 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.

## Junior Solar Sprint – The Photovoltaic Panel

The solar panel is the power source for your car, and will be mounted somewhere on it. You want the panel to collect as much light as possible, and to convert it to electricity as efficiently as possible. Use the investigations below to learn more about your panel and to help you make decisions about how and where to mount your panel.

**Test 1 - Effect of Shadows**

1. Attach the leads of the solar panel to an amp meter (or a multimeter set to read direct current amps). You can use alligator clips, or put the probes from the multimeter snugly in a bend of the wire leads coming from your panel (try to avoid putting new bends in your wire leads if possible). Investigate the effect of shadows on part of the panel. What happens to the amperage of the panel if you cover one of the three cells?

2. What happens if you shade ½ of one of these cells?

**Test 2 - Angle of the Panel**

3. Determine the angle of incidence of the sun. To do this, take a long slender object (such as a pencil) and with one end touching the ground, point the other end towards the sun. When you are pointing directly at the sun, the pointer will not cast any shadow. Then with your protractor, measure this angle and record it below and in the chart in #4.

   Time of day: _________________ Daylight savings time? ____ Yes ____ No

   Angle of incidence __________________

4. Determine if the angle of the panel has an effect on its power output. Using your protractor to measure the angle between the ground and the panel, set your panel at the angles listed in the chart below. Then record the amperage measurement.
   Note: To get an accurate amperage reading, make sure that the tilted side of your panel is

in an orientation that is facing toward the sun!
An angle of 0º would be flat on the ground. A 90º degree angle would be perpendicular to the ground

| Angle of Panel | Amperage measurement |
|---|---|
| **0º** | |
| **20º** | |
| **40º** | |
| **60º** | |
| **Angle of incidence as measured above ___________** | |

5. What angle produced the highest amperage reading?

6. How did this compare to your angle of incidence? What conclusion can you make about which direction to point your panel to get the highest amperage output? (Hint: Think about what angle the sun's rays need to hit the panel to get the highest output)

**Test 3 – Reflectors**

7. Will reflecting more light into the panel significantly increase the amperage of the panel? To find out, use aluminum foil or other shiny surface to reflect more light onto the panel. Take an amperage reading without the reflector first, then add your reflective material. Try varying the angle of the reflector to get the highest reading possible. Record your findings below.

   Amperage without reflector _________________

   Highest amperage obtained using a reflector ___________________

8. What did you have to do to get your highest amperage reading?

**Test 4 – Temperature**

Teams that race full size solar cars will often spray water on the car's solar panel to keep them cool. Investigate how temperature affects your panel.

9. Take an amperage reading from your panel. (Your panel is probably fairly warm from being in the sun during the previous exercises; however, if you have just brought your panel out into the sun, give it a few minutes to warm up a bit before you take your reading.) Record the amperage below. Then take a piece of ice or a cloth dampened with ice water and gently chill the surface of the panel. Take a second reading and record below.

   'Warm' amperage ____________________ 'Chilled' amperage ____________________

10. Did cooling off the panel seem to make a difference? Will this affect the way you handle your vehicle's panel the day of the race?

**Discussion and Design**

With your group, discuss how you might use the findings from your investigations 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 may 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 on/off switch and a fast way to disconnect the panel.