Solar Fountain Sculpture Set
User Guide

Developed by the Rahus Institute–Solar Schoolhouse Program

www.solarschoolhouse.org

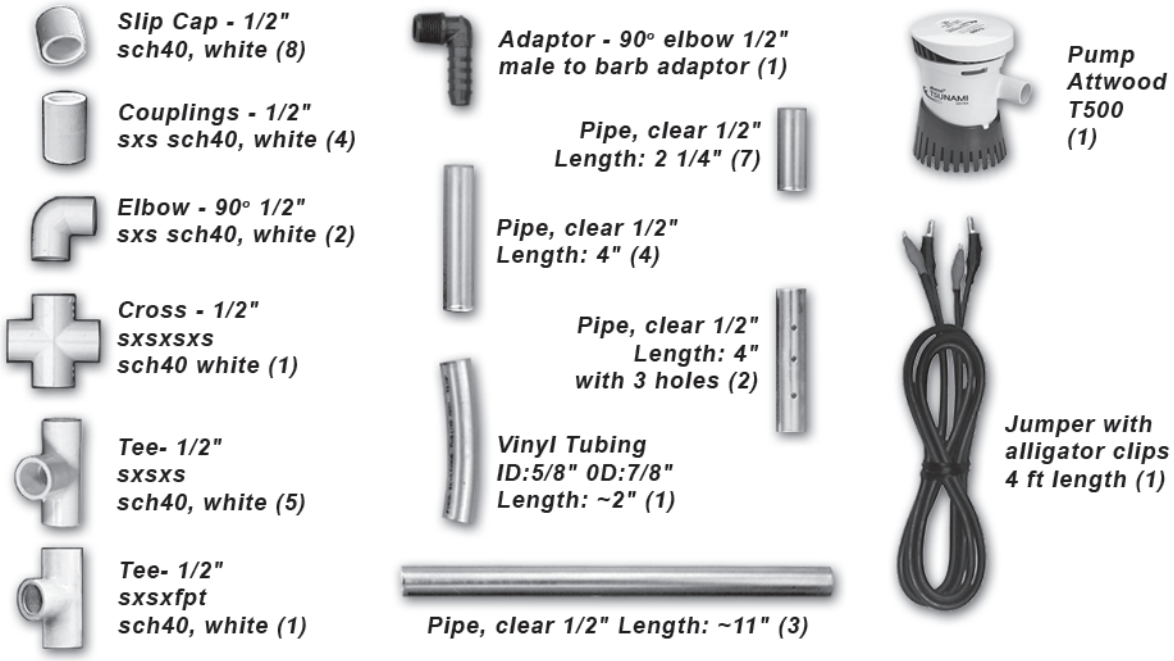
About the Solar Fountain Sculpture Sets

Powering fountains with solar electricity is one of the most effective ways to show the relationship solar-electric modules have with the sun. As the solar modules are aimed more toward the sun, the water pumps more vigorously. Casting a shadow on the modules will slow or stop the water flow. This immediate response lends itself to practical experiments in solar electricity. The head, or height the water is pumped to, can be measured with different configurations of the solar modules. Measurements of the rate of flow (in gallons per minute) can be made. More sophisticated experiments can be done with digital multimeters (not included with the fountain sets, but available at most hardware stores or from the Solar Schoolhouse). With these meters, voltage and current data can be measured from the modules both when powering the pump and when unloaded. The power formula can then be used to develop maximum power characteristics of the modules. This type of experimentation can also provide experience with series and parallel wiring to maximize pump performance.

What's in the Solar Fountain Sculpture Sets

The Solar Schoolhouse makes two models of the Solar Fountain Sculpture Set: the Standard Set (model #SSH-SFSS1) and the Deluxe Set (model #SSH-SFSS2).

The Standard Set can be used with a variety of solar modules, and includes the following:



The Deluxe Set includes all the components of the Standard Set, and adds:

Solar Modules - 3 watt: Rated at 3 volts and 1 amp nominal (4)

Packing up the Solar Fountain Set

It's a good idea to inventory the set before and after each use to make sure all the parts are there. The Inventory List on the next page can be photocopied for this purpose. This is especially important when the fountain set is being shared by several users. In these situations it's good practice to put away all components as neatly as possible, as this makes it easier for the next person using the equipment.

Solar Fountain Sculpture Set - Inventory List

This Fountain Set belongs to _____ **Set #** _____

Check the inventory before and after using this Solar Fountain Set to make sure all the parts are there.

Date	Inventoried by	Item	Start ✔	End ✔	Comments
		8 - Slip Caps			
		4 - Couplings			
		2 - Elbows			
		1 - Cross			
		5 - Tees (slip fit)			
		1 - Tee (threaded)			
		1 - Pump			
		1 - Adapter elbow (threaded & barb ends)			
		7 - clear pipes: 2 ¼"			
		4 - clear pipes: 4"			
		2 - clear pipes: 4" (with 3 holes)			
		1 - Clear vinyl tubing: (about 2" long)			
		3 - clear pipes: (about 11" long)			
		1 - four foot jumper with alligator clips			
		4 - Three watt solar modules (Deluxe Set)			

Building the Solar Fountain Sculpture

This solar fountain sculpture set is made to use the Solar Schoolhouse 3 watt (3v/1A) solar modules. These modules come with the Deluxe Solar Fountain Sculpture Set (model #SSH-SFSS2), and are also found in the Solar Cell Classroom Set and the Solar Power Monitor Set. Each solar module has two wires attached to it. Handle the wires carefully so they stay connected securely to the modules. The ***red wire*** is the ***positive (+)*** connection, and the ***black wire*** is the ***negative (-)*** connection.

Materials Needed

- Solar Schoolhouse Solar Fountain Sculpture Set
- Four – 3 watt (3 volt, 1 amp) solar modules. These are included in the Deluxe Set SSH-SFSS1 (or use modules from other Solar Schoolhouse sets)
- 1 – 5 gallon bucket (or a bigger basin if desired)
- 1 - small board to hold the 3 watt solar modules (~ 20”x20”).
- Adhesive-backed Velcro (or tape) – to hold the modules to the mounting board.

Solar Electricity Basics

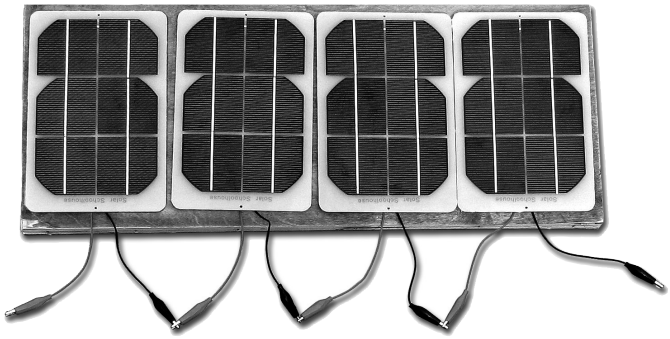
Two basic units of electricity are *volts* & *amps*. Volts measure the force that pushes electrical current through a wire. This current is a stream of electrical particles called electrons. *Amps* (or *amperes*) measure the number of these particles moving in the stream. Each 3 watt solar module is made with six single ***solar cells***. These cells, like all silicon solar cells, produce ~0.5 volts (at 25°C). Larger cells supply more amps than smaller cells.

When each 3 volt solar module was made, the six individual cells were wired together *in series* by attaching the positive connection of one cell to the negative connection of the next. Wiring in series adds the voltage of each cell together, so six 0.5 volts cells produce a total of 3 volts when wired together in the solar module. The total current (amperage) is the same as a single cell.

Making a Series String

We can wire four of the 3 volt modules together in series (+) to (-) to make a 12 volt ***‘series string’*** (also called a ‘solar array’). This 12 volt solar power supply can run the 12 volt submersible pump in the fountain set. Series wiring connects electrical devices in a chain or string, and the electric current will flow in one direction: first through each module, then through the pump, and finally back through the modules again.

Four - 3 watt (3 volt) modules wired in series to make a 12 volt series string (or 12 volt ‘solar array’)



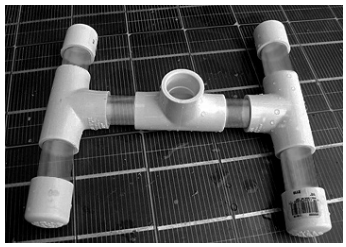
To build a series string, start by mounting the modules on the wooden board. This will keep them together, and make it easier to change their orientation when needed. A good way to do attach them is with Velcro. Stick a piece of Velcro on the back of each 3 watt module, and the opposite Velcro piece on the mounting board. Then clip the red (+) wire of each module to the black (-) wire of the next, as shown in picture above.

Building the Fountain Structure

Now that we have a power supply we can make the fountain structure. The pvc fittings in this set are ½” slip fittings – no solder, glue, or other tools are required. These fittings are commonly found at local hardware stores if you’d like to add to your set. We’ve included clear pipe for viewing the water flowing in the pipes.

Building the Base

Using 3 slip fit tees, 4 caps, and 6 short pipe pieces, assemble the base in an “H” shape as shown in the picture on the right. Twist the pipes into the fittings for a snug fit. This will give the fountain a sturdy foundation.



Stable H-Base

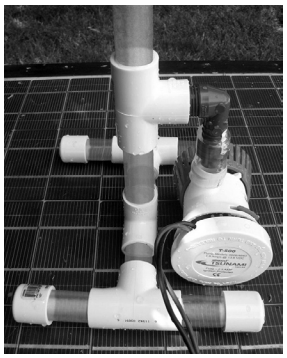
Pump Sub Assembly

Pump Sub Assembly

One of the tees has threads on the inside of one connection. Carefully screw the threaded end of the 90° Adapter Elbow into this. Then push the flexible vinyl tubing onto the other (barbed) end of the Adapter Elbow. Add a short piece of pipe to the tee as shown in the picture on the left.

Next attach the pump to the vinyl tubing, and then connect the Pump and Sub Assembly unit to the H-base as shown in the picture to the right.

To complete the fountain, twist a long clear pipe into the last connection on the tee, and put a coupling on top of the pipe.

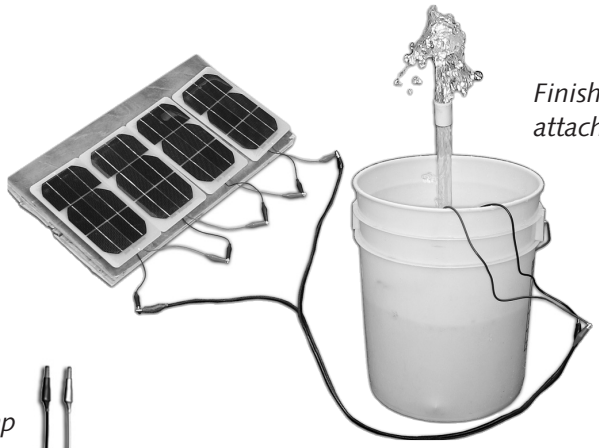


Pump & Sub Assembly connected to the base

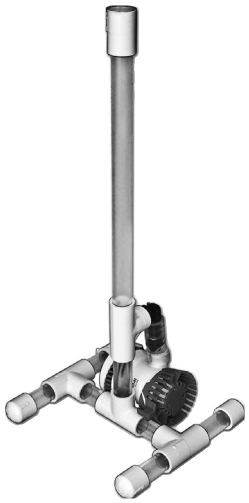
Connect the Fountain to the Solar array & Make a Splash!

Put the fountain sculpture in a 5 gallon bucket. Fill up the bucket about three-quarters full with water.

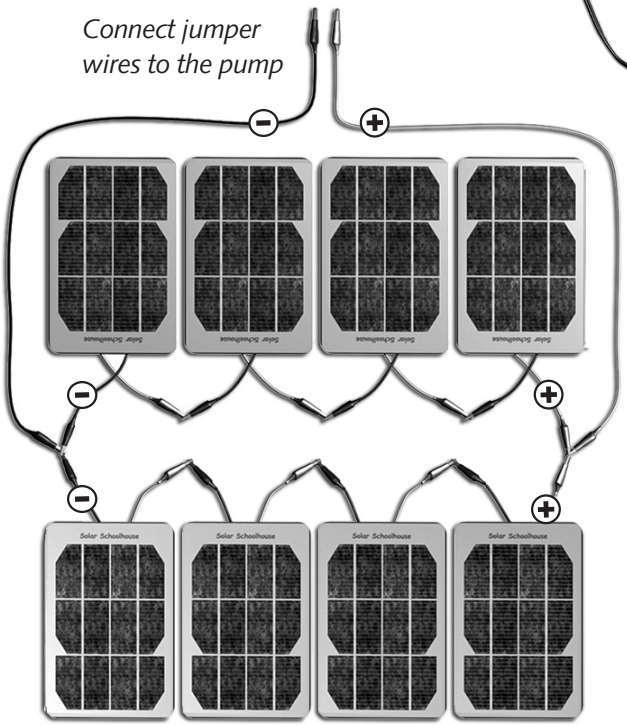
The fountain sculpture should rest on the bottom of the bucket with the centerpiece pointing straight up. If not, you can put a heavy object (like a rock or brick) to weigh it down. Extend the wires from the pump to outside of the bucket. Connect the pump wires to the 12 volt solar array using the four-foot jumper. Put the completed project in the sun and watch it come alive!



Finished Solar Fountain attached to solar array



Finished Solar Fountain



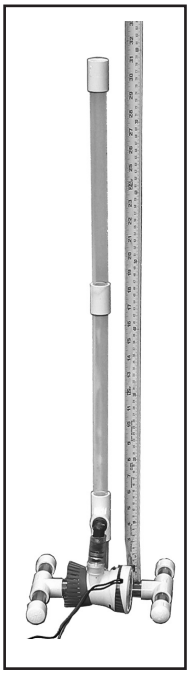
Attach a second series string in parallel to increase amperage and maintain voltage

See How High the Fountain Can Go

The head, or height the water is pumped to, can be measured with a tape measure. If you have more modules, try making another 12 volt series string, and connect it *in parallel*. Clip the last positive wires from the series strings together, and clip together the two negative wires. Then connect the 2-string array to the pump with jumper wires. Parallel wiring adds amps, and keeps the same voltage. This gives the pump more power on cloudy days.

Create Your Own Designs

This is just one way to build the Fountain structure. Experiment with different ways of connecting the pieces. Visit the local hardware store to find other ½" PVC slip fittings for your designs.



Measuring pump head

Testing the Solar Fountain - page one

Using Digital Multimeters to Measure Power

Note: The Solar Schoolhouse Power Monitor Set (available at www.solarschoolhouse.org). includes a custom test station with dual meters for doing the following experiments. For directions on using digital multimeters see the Solar Cell Classroom Set User Guide, available as a free download from the Solar Schoolhouse website.

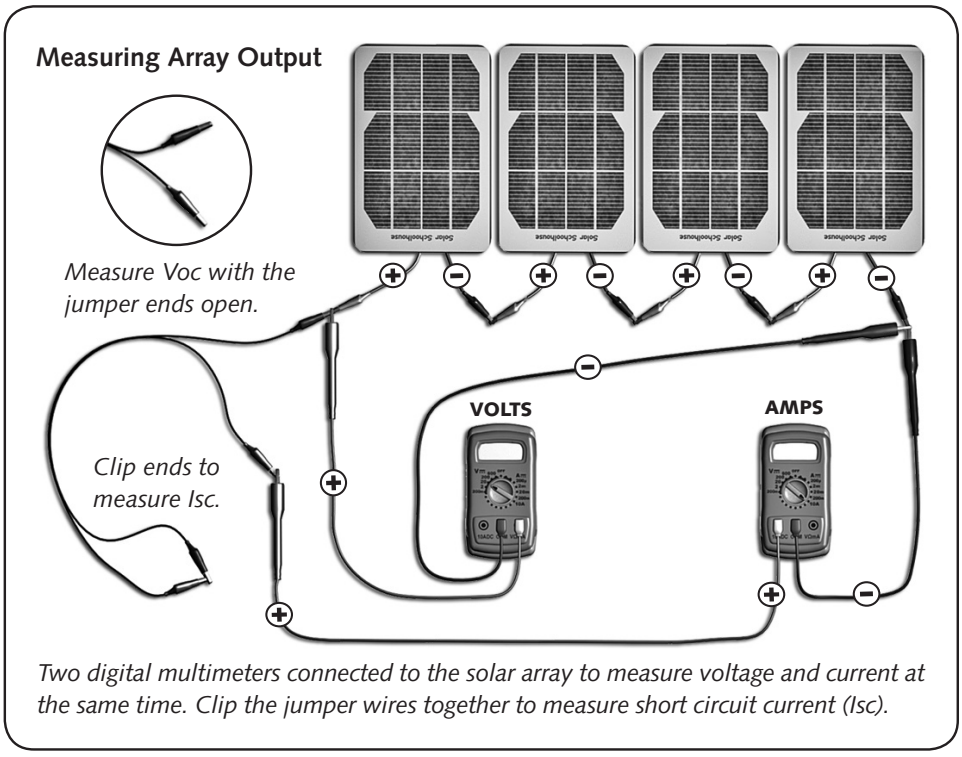
Measuring Array Output

The 12 volt solar array (like all solar cells and modules) has 3 characteristic electrical measurements: Open Circuit Voltage (Voc), Short Circuit Current (Isc), and the Maximum Power Point for current (Imp) and for voltage (Vmp). Voc and Isc are measured without a load, while Imp and Vmp are measured with a load.

Two digital multimeters can be wired together to make these measurements simultaneously. One meter is set up to measure amps, the other is set up for volts, and the solar array is connected as shown in the picture on the right. This setup lets us measure current and voltage at the same time.

Jumper leads can be attached as shown. The system will measure short circuit current (Isc) when the jumper lead ends are clipped together. Notice that the voltage drops dramatically when the circuit is shorted. The amperage reading shows the maximum current the array can produce.

Un-clip the jumper ends, and the meters measure the open circuit voltage (Voc) and current. This voltage reading shows the maximum volts the array can produce. This voltage is available only when no load is attached to the jumper.



Two digital multimeters connected to the solar array to measure voltage and current at the same time. Clip the jumper wires together to measure short circuit current (Isc).

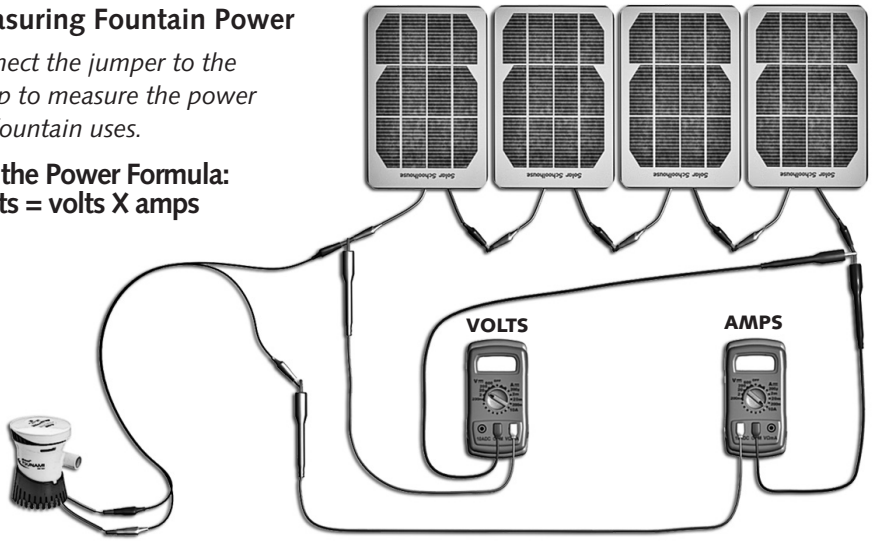
Measuring Power

When the jumpers are connected to the fountain pump, the meters will measure the power consumed by the pump. Remember: power is measured in watts, and is the product of volts multiplied by amps. Simply multiply the reading from both meters to get the power used by the fountain at any instant.

Measuring Fountain Power

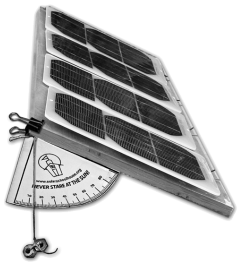
Connect the jumper to the pump to measure the power the fountain uses.

Use the Power Formula:
Watts = volts X amps



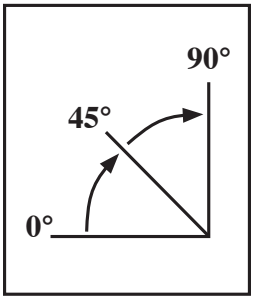
Testing the Solar Fountain - *page two*

MAXIMIZING POWER - Optimum Orientation



Sun Angle Quadrant clipped to solar array

Using the dual multimeter setup on the last page, you can measure Voc and Isc at a variety of azimuth and tilt angles. Mark a "Compass" on the sidewalk with chalk, and put the solar array and meters in the middle of it. Use a protractor or Sun Angle Quadrant (free template available from solarschoolhouse.org) to measure tilt angles. For ease of use, clip the Quadrant to the array as shown on the left. Record the Voc readings with the jumper ends open. Then clip the ends together and take the Isc readings. Be sure not to shade the array while taking measurements.



Date: **Time:**

Conditions (clear, partly cloudy, warm, etc.):

Azimuth	Tilt Angle	Voc*[Volts]	Isc**[Amps]	Power***[Watts]
East (90° clock-wise from North)	0° (horizontal)			
East	45°			
East	90° (vertical)			
South (180°)	45°			
South	90°			
West (270°)	45°			
West	90°			
North (0°)	45°			
North	90°			

*Voc = Voltage Open Circuit; Measure this with the jumper ends open. Maximum voltage with no load.
**Isc = Short Circuit Current [Amps]; a complete circuit with no load. Measure this with the jumper ends clipped together. The voltage meter should approach Zero.
***Power [Watts] = Volts x Amps

Graph your data using bar graphs on another piece of paper. Answer the following questions:

1. What varies (changes) most with solar module orientation, amps, volts or watts?

2. Why do you think that is?

3. What are the azimuth and tilt angles for maximum power?

4. What are the azimuth and tilt angles for least power?

5. How would your results change if these experiments were conducted 6 months from now?

Testing the Solar Fountain - *page three*

PUMPING WATER - Flow Rate vs. Sunlight

Measure the fountain flow rate using dual multimeters and a stop watch.
Use two pvc elbows and two long clear pipes to make an "L" attachment as shown below. Connect it to the fountain base and place the assembly in a 5 gallon bucket about three-quarters full of water. Put a measuring container (like a measuring pitcher or a 1 gallon milk jug) under the outside end of the "L." Connect the pump to the multimeters with a jumper as shown on the bottom of "*Testing the Solar Fountain - page 1*," and try out the system.

To begin testing, disconnect one jumper clip from the pump wire, and point the solar array at the sun to maximize power output. Reconnect the jumper and start the stop watch at the same time. Note Volts and Amps. When the measuring container is full (i.e. 1 gallon), disconnect the jumper and stop the watch at the same time. Record the time. Fill in the chart: calculate the gallons per hour (gph) and Watts (Watts = Volts x Amps). If you have more solar modules, connect more 12 volt arrays (or modules) in parallel to increase amperage as shown on page 4. Add one array (or 12 volt module) at a time, and repeat the exercise. See if you can maximize the flow rate per maximum specifications for the pump.

Note for 3 volt modules: Wire (4) - 3V modules in series (positive to negative, positive to negative) to make 12V arrays. Wire these 12V arrays together in parallel (connect positive leads to positive leads, & negative leads to negative leads) to increase amperage and maintain 12 volts.

# of 12V Modules (or 12V Arrays)	Volume (gal) or (l)	Time min (hrs)	gph (lph)	Volts	Amps	Watts
1						
2						
3						
4						

1. Chart gph (x-axis) vs. Watts (y-axis) on graph paper. Did you push the pump to its flow capacity?

2. How can you increase flow rate on cloudy days? Why does this work?

3. On a separate page analyze the pros and cons of using solar energy for water pumping in developing countries, or water pumping for livestock, or water pumping for irrigation on California's farms.

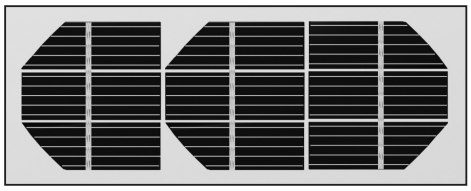
Attwood Pump – Specifications
500 Gallons Per Hour @ 13.6V open flow (no lift)
450 gph @ 12V open flow (no lift)
max amp draw
1.5A @ 13.6 V
1.3 A @ 12V
Reference:
www.attwoodmarine.com
Bilge pump: Attwood T500
3.785 liters = 1 gallon

The Solar Fountain Parallel Set

Using 12 volt - 1.25 Watt Modules

WARNING: Connect the 12 volt - 1.25 watt modules with PARALLEL wiring only!
In other words: Connect yellow (+) wires to yellow (+) wires, and white (-) wires to white (-) wires. Connecting these modules in series (yellow to white, and yellow to white) may increase the voltage to potentially dangerous levels.

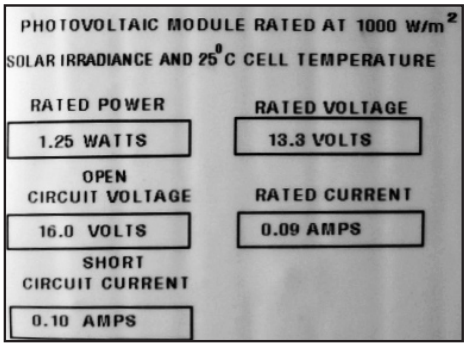
Background: We've acquired a large quantity of small solar electric modules (laminates). These 1.25 watt (rated @ 13.3volts, 0.09amps) modules were originally designed to charge a small 12v battery to power a remote GPS signal. The modules have no frame, hence the term "**laminates**." This represents modern solar module construction, with mono crystalline silicon solar cells, tempered glass top, standard water tight encapsulation, and 7 ft wire leads with a waterpack connector.



1.25 watt Solar laminate

- no frame
- tempered glass
- 7 ft wire leads
- waterpack connector (use or discard)
- dimensions: 210 x 85 x 4 mm (8 5/16 x 3 3/8 x 1/8 inch)

Electrical specifications



How you can tell what VOLTAGE a solar module will produce?

1. Since each individual silicon solar CELL produces ~0.5Volts, and when cells are wired in SERIES the **voltage is additive**, you can count the number of solar cells in the module and divide by 2 to ESTIMATE the module voltage. This allows a designer to choose the appropriate solar module (at a voltage slightly higher than what the load is designed for) to power any load.
2. Use a digital multimeter (DMM) to measure the module voltage by clipping the DMM leads to same polarity wires from the solar cell. For these modules, the white wire (from the solar cell) and black wire from the DMM are both negative, while the yellow wire (solar cell) and red wire (DMM) are positive. Put the module in the sun and read the meter.

SAVPAA
SERIES ADDS VOLTAGE (SAV)
PARALLEL ADDS AMPS (PAA)

When to use series and when to use parallel wiring?

1. Look at the load you are trying to power. In this example, the Attwood T500 bilge pump is rated at 12Volts and 1.5 amps max.
2. Generally, try to design a solar 'array' that provides a slightly higher voltage than what the load rating is. Here are 2 possible solutions:
    a. The 13.3Volt (*0.09amp) solar laminate has a voltage rating that is just above the 12volts called for by the pump, but the amps are very low compared to the pump rating. In this case, you'd want to wire several (qty 6-15) solar laminates in PARALLEL to increase the amps, but not the voltage.
    b. A single Solar Schoolhouse 3V(*1Amp) solar module doesn't have enough voltage to power the pump, but has plenty of amps. In this case, you'd want to wire four 3V modules in SERIES to increase the overall voltage of the array, but not the amps.

Remember: Connect the 12 volt modules in PARALLEL only! Only the 3 volt modules should be wired in SERIES to avoid potentially dangerous voltage levels.

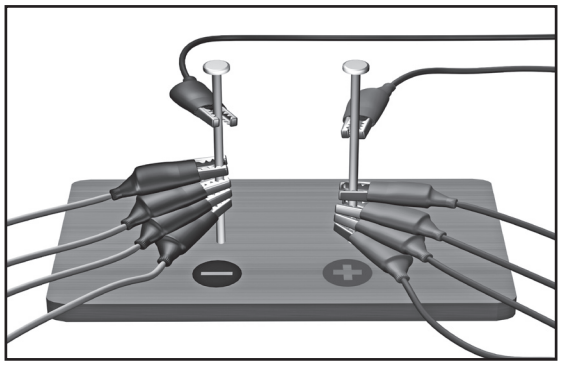
Powering a Solar Fountain – 12V bilge pump

If you start with a 12volt bilge pump (Attwood T500 is good as it needs the least amps to start pumping), then the challenge is to see how many 1.25w modules are needed, in **parallel** (to increase amps), to get the pump to work. One idea is to create a "leaves on a tree" sculpture to mount the modules, with all the wires connected in parallel to power the pump.

You'll need to innovate on how to mount the modules (Velcro? or?) and how to make the connection between the modules and the pump. Does it need a switch?

The diagrams below show how to use the nailed "Terminal Block" to safely connect all the positive leads on one nail, and the negative leads on the other. Then connect the leads from the pump to the nails.

Questions:
Contact Tor Allen tor@rahus.org 707-829-3154



Close up detail of connections