Sun Angle Science Kit

(Order Code KW-SASK)

This kit explores the basics of photovoltaic (PV) solar panels. When installing PV panels, the professionals study the angles of the sun to make sure that the solar panel is tilted to the correct angle. Study how the angle of your solar panels affects the power output, while also experimenting with series and parallel circuits and water pumping applications.

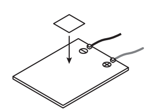
What’s Included

A plastic bin containing

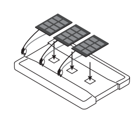
- Power Output Pack
- Sound and Light Board
- Small Water Pump
- Tubing*
- 2V/400mA Solar Panels (3)
- Chipboard Sheets* (3)
- Hook-and-pile* (3)
- Protractor
- Digital multimeter

Assembly Instructions

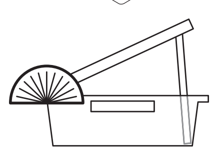
1. Attach the solar panels to the lid of the box. Peel off the adhesive backing of the hook-and-pile patches and apply one piece to the back of each solar panel.



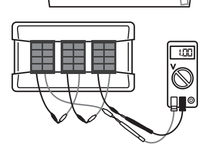
2. Apply the corresponding pieces of fastener to the box lid, spacing them evenly and allowing room for all three solar panels.



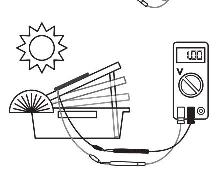
3. Once the panels are secured, you can use the chipboard to hold the lid open. Use the protractor to measure the angle of the lid in relation to the rest of the box. The chipboard can be cut or moved to adjust the box angle.



4. Hook the multimeter to one of the solar panels (see "Wiring Your Solar Panels" for more on wiring your solar panels). Secure the lid such that the panels are pointed at the sun. Remember not to look directly at the sun!



5. Gradually open the lid more and measure the voltage from the solar panel. The voltage should gradually increase, reach a maximum, then gradually decrease. The maximum voltage indicates the point at which the solar panel (and lid) is most directly pointed at the sun. Use the protractor



*This part is a consumable and is excluded from the warranty.

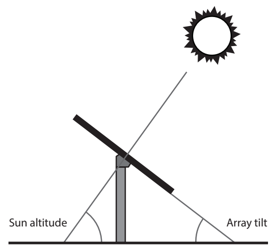
to measure the lid's angle.

6. Compare your measured solar angle with charts based on geographic location and time of year: **http://solardat.uoregon.edu/ SunChartProgram.html**

Note: With solar panels, the voltage is somewhat sensitive to how directly the panel points at the sun. The total power output is even more sensitive to the angle toward the sun. If you want to see a larger difference with this experiment, hook an electrical load (like the water pump) to the solar panel, and measure the amps (or calculate the watts) as you change the angle.

Setting the Box Angle

You can use predetermined angles and test which provides the highest output. Using the protractor, set the box lid to angles of 20°, 30°, 40°, or any measurements you choose. Of these angles, measure which one supplies the highest voltage. Assume the angle with the highest voltage is the angle most directly pointed at the sun, and conduct the rest of your experiments at that angle.



Array tilt and sun altitude angles

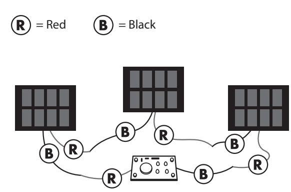
Another method is to cut a triangle from the chipboard included in your kit. This triangle will be used to hold the box lid open at preset angles during your experiments. Select three angles that work best for your experiments and open the box to these angles using the protractor. Determine how tall your triangle stand needs to be to hold the box at each angle. You will end up with a triangle with sides of three different lengths, each corresponding to a specific box angle.

Note: The relative angle between the sun and the solar panel will change during the day as the sun moves. You may need to re-measure the angle as time passes.

Wiring Your Solar Panels

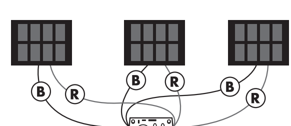
Wiring in Series

In a series circuit, the voltage (volts) will increase with each additional panel, but the current will stay the same. To connect your panels in series, daisy-chain the panels, from the red (+) wire from one panel to the black (–) wire of the next and so on.



Solar panels wired in series

Try measuring the voltage of one solar panel. Next, connect two solar panels in series and measure voltage. Then connect three solar panels in series and measure the voltage. Using your multimeter, you should see the total voltage increase as you add panels to the series.



Solar panels wired in parallel

Wiring in Parallel

If you wire the panels in parallel, the current (amps) will increase with each additional panel, but the voltage will not change. To connect your panels in parallel, connect all the red (+) wires together and all the black (–) wires together.

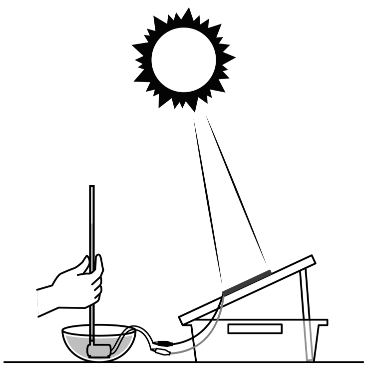
Experiments

Water Pump Experiments

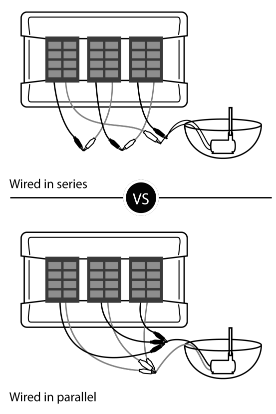
Start by filling a large cup or bowl with water. Attach the provided tubing to the water pump, then connect the wires from one solar panel to the wires on the pump. Submerge the pump in the water and point the solar panel at the sun. Hold the tubing straight up and down and measure how high the water rises in the tubing.

Now connect two solar panels wired in series and repeat the water pump experiment. How high does the water rise using two panels in series? Repeat the experiment using all three solar panels wired in series.

Now that you have experimented with panels in series, try pumping water with panels in parallel wiring. Wire two panels in parallel and connect them to the water pump. Measure how high the water rises in the tube. Repeat the experiment using all three solar panels wired in parallel.



Hold the tubing straight up and down and measure how high the water rises.



Wired in series vs. *wired in parallel*

> **Note:** There is a correct direction of rotation for the water pump—it will pump water higher when it is wired with the correct polarity. If you are not sure which is the correct wiring, reverse the polarity and see if the water rises higher or lower in the tube. Choose the polarity that pumps the highest.

Based on the results, do you think that the performance or efficiency of the water pump is affected more by voltage or by amperage?

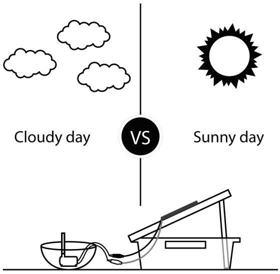
You can also measure the volume of water pumped instead of how high the water rises in the tube. Set up the water pump so that it flows from your bowl into a measuring cup (1 or 2 cups). Your bowl and the measuring cup should be at the same height. Using a stopwatch, time how long it takes to fill the measuring cup using the water pump powered by solar panels. Which circuit arrangement pumps water faster—series or parallel?

You can also use the 1″ section of 1/8″ diameter tubing to make a more dramatic "fountain." Cut 1″ off of the 5 ft 1/4″ tubing and insert it on the water pump spout. Now place the thinner tubing inside the 1/4″ tubing to constrict the flow. This will make the water squirt higher!

Note: The sun has much more power than a light bulb, so experiment with your solar boat outside on a sunny day whenever possible. On a clear, sunny day, the average solar energy received by the earth is about 1,000 watts per square meter. That means you would have to fit ten 100 watt light bulbs in a 3 ft x 3 ft square to even come close to the power you can get from the sun!

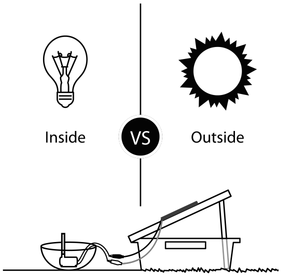
Other Experiments

Here are some other interesting experiments to try:



1. Compare the results from the experiments above on a cloudy day *vs*. a sunny day.
2. Place a colored filter or shade over a solar panel and see how the voltage is affected. You can also do this inside a classroom using different colored slides from an overhead or LCD projector as your light source.
3. Compare the power of a solar panel from indoor (artificial) light *vs*. outdoor sunlight.
4. Place one solar panel in a refrigerator. Leave one at room temperature, and warm the third in direct sunlight. Place the three solar panels (all at different temperatures) in direct sunlight and measure their output. Which panel provides the highest output? Why?

Full-Day Experiment



1. At 9:00 am, place your solar box somewhere the sun will shine continuously throughout the day. Make sure the box is level and won't be bothered by the weather or anything else.
2. Measure the DC voltage from the solar panel.
3. Measure the voltage every hour until 3:00 pm.
4. Analyze the data. What time of day had the highest voltage? Why? What time of day had the lowest voltage? Why?
5. You can conduct this experiment in two ways: Keep the box in a fixed position, facing directly south, at the same angle the whole day (imitating a solar panel that is mounted on a fixed base). Or, every hour, rotate the box to follow the sun, and for each measurement adjust the lid angle to the maximum output. (This imitates a solar panel that is mounted on a variable base).

Long Term Experiment

1. Find a place for the solar box that will not be in the shade for the entire semester. Again, make sure the box is level and won't be bothered.
2. For each day, record the maximum voltage, the direction the box is pointed (north, south, etc.), the angle of the box lid, the date, the time of day, and the cloud cover on a scale of 0–5 (0 is no clouds, and 5 is maximum cloud cover).
3. Repeat the measurements at least once per week for the semester.
4. Analyze your data. How does it compare to the website with the sun-angle data? (http://solardat.uoregon.edu/SunChartProgram.html)

Additional Resources

For more information about wind energy, see KidWind's document, *Learn Wind*, available at **http://learn.kidwind.org/sites/default/files/learn_wind.pdf**

NOTE: Vernier products are designed for educational use. Our products are not designed nor recommended for any industrial, medical, or commercial process such as life support, patient diagnosis, control of a manufacturing process, or industrial testing of any kind.

Warranty

Vernier warrants this product, excluding consumables, to be free from defects in materials and workmanship for a period of five years from the date of shipment to the customer. Consumables are clearly marked on Page 1 of the user manual.

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