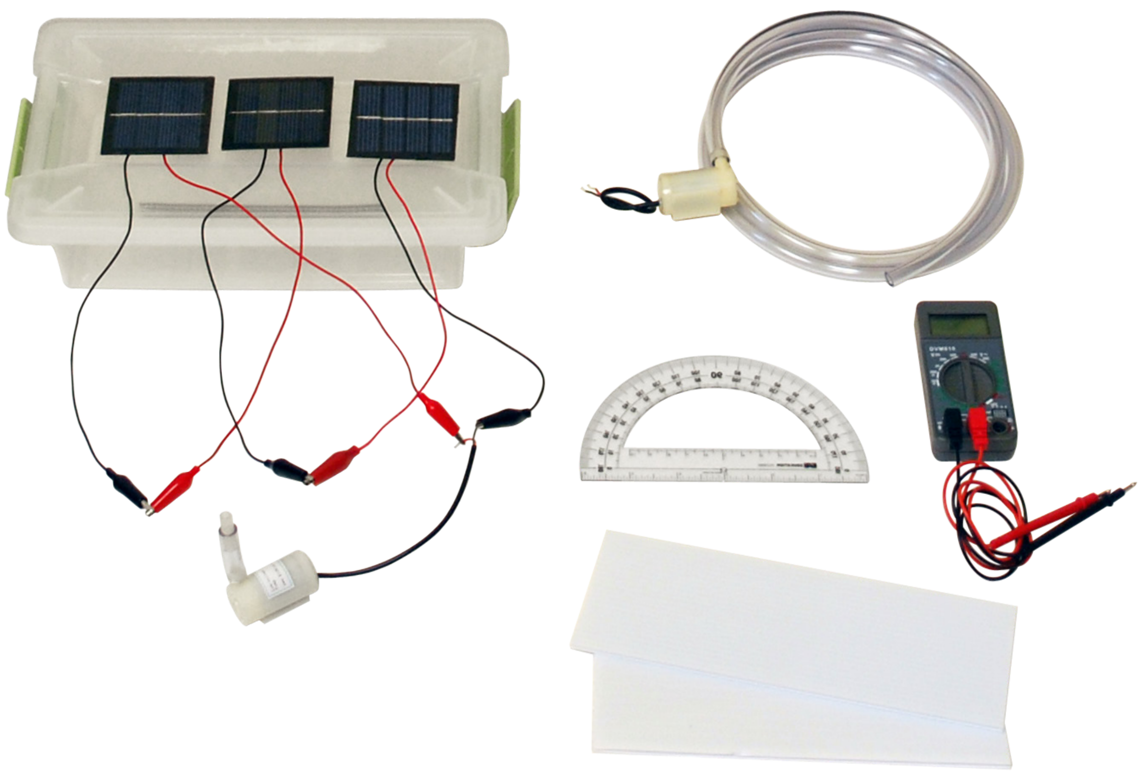
SUN Angle Science Kit



instructions

Made in US

We source domestically whenever possible, and assemble and pack our kits in St. Paul, MN.

Our plastic components are made from recycled resins.

We Give Back

Proceeds from your purchase help us train and supply teachers.

About KidWind

The KidWind Project is a team of teachers, students, engineers, and practitioners exploring the science behind wind energy in classrooms around the US. Our goal is to introduce as many people as possible to the elegance of renewable energy through hands-on science activities which are challenging, engaging, and teach basic science principles.

While improving science education is our main goal, we also aim to help schools become important resources for both students and the general public, to learn about and see renewable energy in action.

Thanks to…

We would like to thank the Wright Center for Science Education at Tufts University for giving us the time and space to develop this idea into a useful project for thousands of teachers.

We would also like to thank Trudy Forsyth at the National Wind Technology Center and Richard Michaud at the Boston Office of the Department of Energy for having the vision and foresight to help establish the KidWind Project in 2004. Lastly, we would like to thank all the teachers for their keen insight and feedback on making our kits and materials first rate!

Wind for All

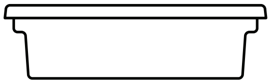
At KidWind, we strongly believe that K–12 education is an important foundation for promoting a more robust understanding of the opportunities and challenges that emerging clean energy technologies present.

The Wind for All program seeks to support teachers and students all over the globe who do not have the financial capacity to access our training programs and equipment. We believe that all teachers and students—regardless of where they live or what school they attend—must be part of the clean energy future.

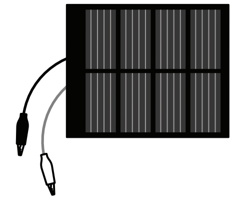
A Note on Reproduction

V1.0

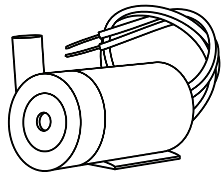
Parts



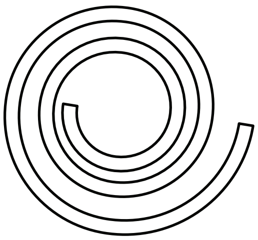
Plastic box and lid (1)



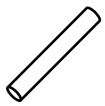
Solar panel (3)



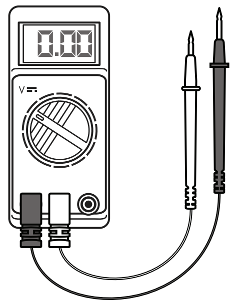
Water pump (1)



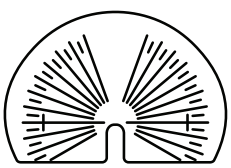
Tubing, 5 ft. (1)



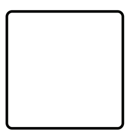
Tubing, 1 ft. (1)



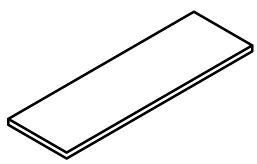
Multimeter (1)



Protractor (1)



Velcro (3)



Corrugated plastic (2)

SUN ANGLE SCIENCE KIT

Parts List

1 Plastic box and lid

3 Solar panels, 2 volt

1 Water pump

1 Tube, 1/4 inch, 5 foot length

1 Tube, 1/8 inch, 1 foot length

1 Digital Multimeter

1 Protractor

3 Velcro patches

2 Sheets of corrugated plastic

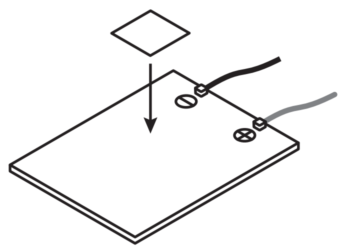
Other useful items (not included)

Scissors/hobby knife

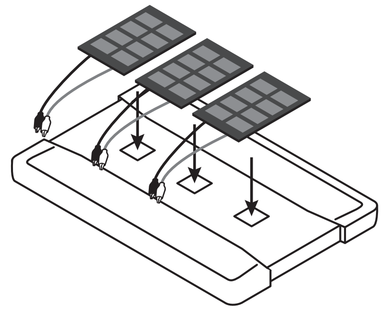
Duct tape

Marker

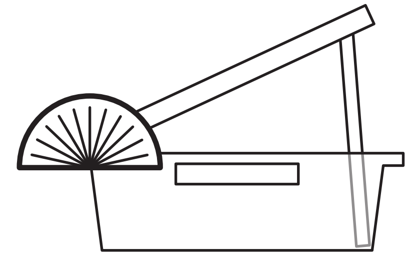
Assembly Instructions



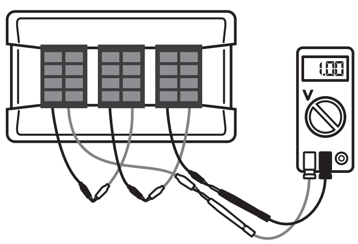
1. Attach the solar panels to the lid of the box. Peel off the adhesive backing of the Velcro patches and apply one piece to the back of each solar panel.



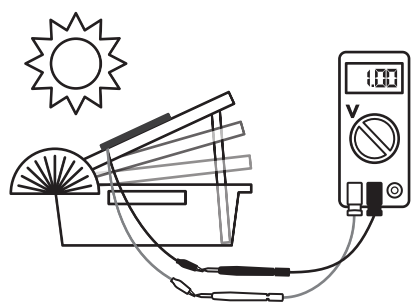
2. Apply the corresponding pieces of fastener to the box lid, spacing them evenly and allowing room for all three solar panels.



3. Once the panels are secured, you can use the corrugated plastic sheet to hold the lid open. Use the protractor to measure the angle of the lid in relation to the rest of the box. The plastic 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!



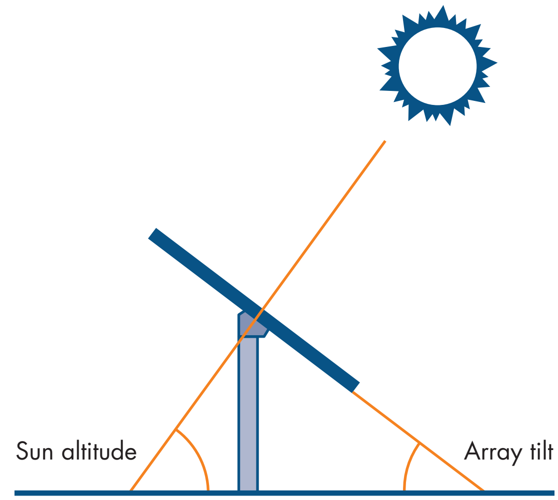
5. Gradually open the lid more and measure the voltage from the solar panel. The voltage should gradually increase, hit a maximum, then gradually decrease. The maximum voltage indicates the point at which the solar panel (and lid) is most directly pointed at the sun. Use the protractor to measure the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

Introduction

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.



Array tilt and sun altitude angles

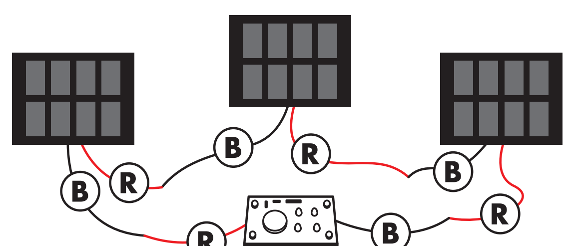
Setting The Box Angle

You can use predetermined angles and test which provides the highest output. Using the protractor, set the box lid to angles of 20 degrees, 30 degrees, 40 degrees, 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.

Another method is to cut a triangle from the corrugated plastic sheet 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.

R = Red B = Black



Solar panels wired in series

Wiring Your Solar Panels

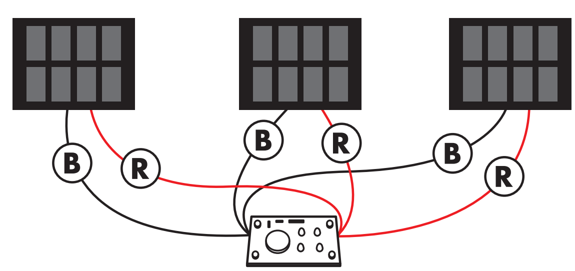
Wiring in Series

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.

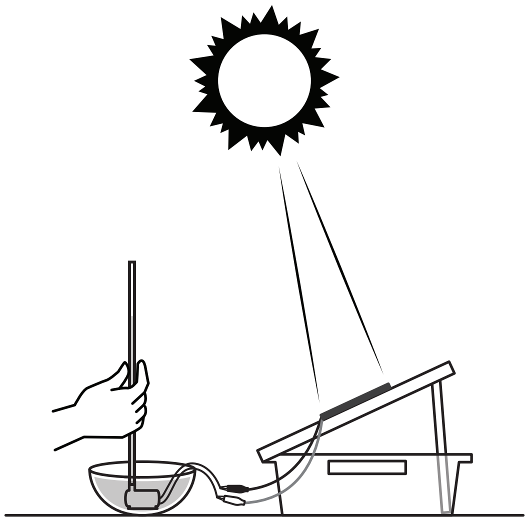
Try measuring the voltage of one solar panel. Next, connect two solar panels in series and measure voltage. Then connect three solar panels in series and measure the voltage. Using your multimeter, you should see the total voltage increase as you add panels to the series.

Wiring in Parallel

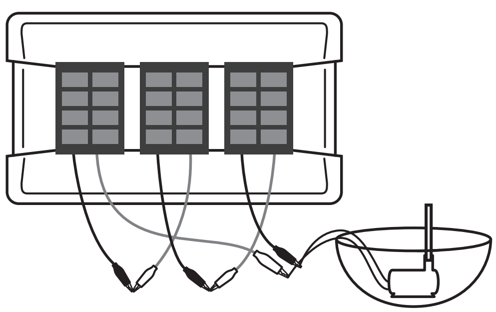
If you wire the panels in parallel, the current (Amps) will increase with each additional panel, but the voltage will not change. To connect your panels in parallel, connect all the red (+) wires together and all the black (-) wires together.



Solar panels wired in parallel

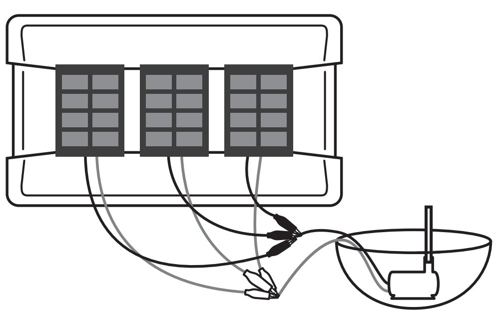


Hold the tubing straight up and down and measure how high the water rises.



Wired in series

VS



Wired in parallel

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.

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're 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.

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.

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?

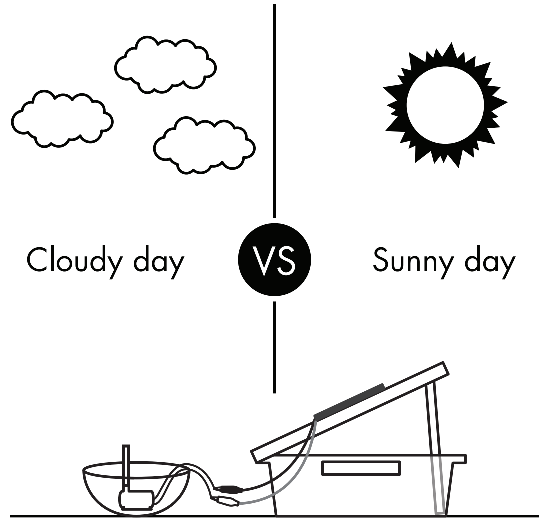
You can also use the 1 inch section of 1/8 inch diameter tubing to make a more dramatic "fountain." Cut 1 inch off of the 5 foot, 1/4 inch tubing and insert it on the water pump spout. Now place the thinner tubing inside the 1/4 inch tubing to constrict the flow. This will make the water squirt higher!

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 foot x 3 foot square to even come close to the power you can get from the sun!

Other Experiments

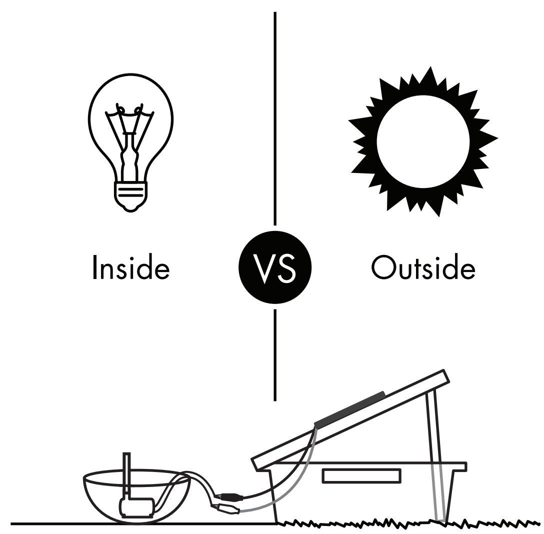
Here are some other interesting experiments to try:

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?



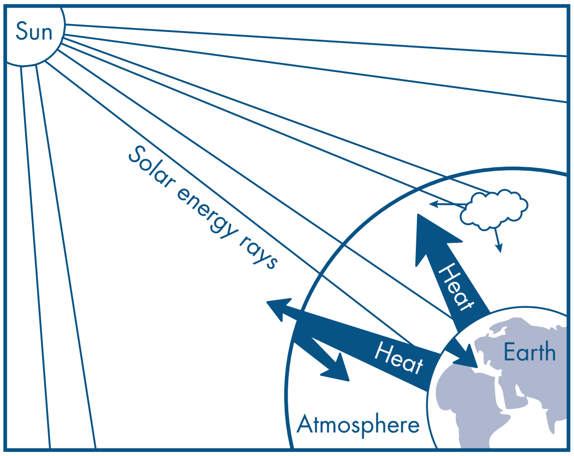
Full-Day Experiment

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).

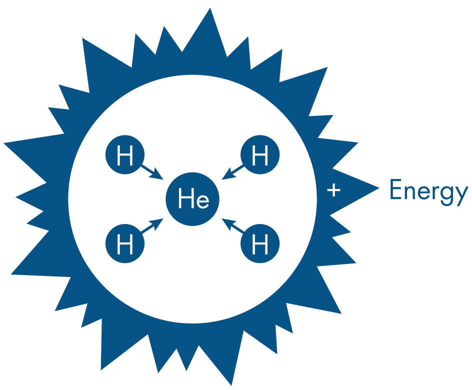


Long Term Experiment

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)



The Greenhouse Effect



Nuclear Fusion

What is Solar energy? How does it work?

Every day, the sun sends out an enormous amount of energy. It radiates more energy in one second than the world has used since time began! This radiant energy, also known as solar energy, is vital to us because it provides the world directly—or indirectly—with almost all of its energy. In addition to providing the energy that sustains the world, solar energy is stored in fossil fuels and biomass, and is responsible for powering the water cycle and producing wind!

Solar energy comes from within the sun itself. Like other stars, the sun is a big ball of gases, mostly hydrogen and helium. The hydrogen atoms in the sun's core combine to form helium and radiant energy in a process called *nuclear fusion*. This process creates a large amount of radiant energy, which is emitted into space. Only a small portion of the energy radiated by the sun into space strikes the earth, one part in two billion. Yet this amount of energy is enormous. Every day, enough energy strikes the United States to supply the nation's energy needs for one and a half years!

Solar energy is considered a renewable energy source. Renewable sources of energy are resources that are continually renewed by nature, and hence will never run out. Solar power is considered renewable because the nuclear (fusion) reactions that power the sun are expected to keep generating sunlight for many billions of years to come.

Solar Electricity and Photovoltaic Systems

Solar energy can also be used to make electricity. This is done largely through the use of photovoltaic (or PV) systems. Photovoltaic comes from the words photo, meaning light, and volt, a measurement of electricity. Photovoltaic cells are often called solar cells. They convert light directly into electricity.

The photovoltaic effect is the basic physical process through which a PV cell converts sunlight directly into electricity. PV technology works any time the sun is shining, but more electricity is produced when the light is more intense and when it is striking the PV modules directly when the rays of sunlight are perpendicular to the PV modules.

Sunlight is composed of photons, or bundles of radiant energy. When photons strike a PV cell, they may be reflected or absorbed, or transmitted through the cell. Only the absorbed photons generate electricity. When the photons are absorbed, the energy of the photons is transferred to electrons in the atoms of the solar cell.

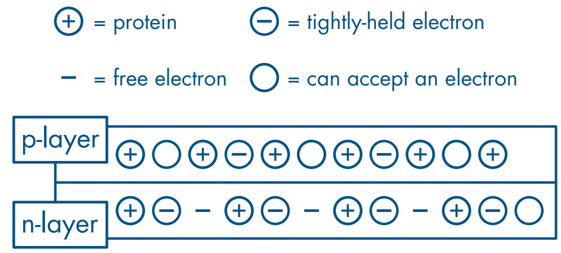
With their newfound energy, the electrons are able to escape from their normal positions associated with their atoms to become part of the current in an electrical circuit. By leaving their positions, the electrons cause holes to form in the atomic structure of the cell into which other electrons can move.

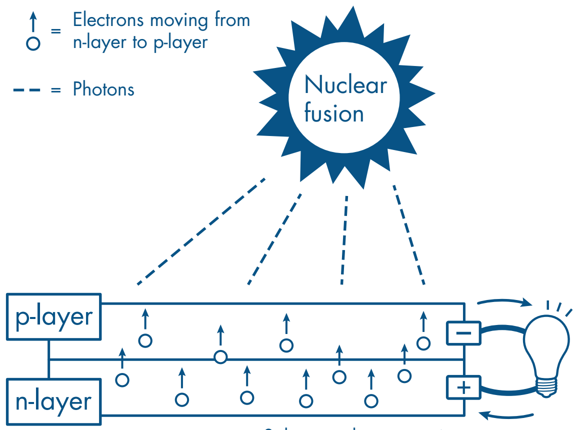
Solar cells are usually made of two thin pieces of silicon, the substance that makes up sand and the second most common substance on earth. Silicon is used because it is a semiconductor, or a solid that is in between a conductor and an insulator of electricity. One piece of silicon has a small amount of boron added to it, which gives it a tendency to attract electrons. It is called the P-Layer because of its positive tendency. The other piece of silicon has a small amount of phosphorous added to it, giving it an excess of free electrons. This is called the N-Layer because it has a tendency to give up negatively charged electrons. When the two pieces of silicon are placed together, some electrons from the N-Layer flow to the P-Layer and an electric field forms between the layers. The P-Layer now has a negative charge and the N-Layer has a positive charge.

When the PV cell is placed in the sun, the radiant energy energizes the free electrons. If a circuit is made connecting the layers, electrons flow from the N-Layer through the wire to the P-Layer. The PV cell is producing electricity—the flow of electrons. If a load such as a light bulb is placed along the wire, the electricity will do work as it flows.

Compared to other ways of producing electricity, PV systems are expensive. This is mainly because PV cells require silicon that is extremely pure. This level of purity makes the silicon expensive. However, despite the high cost, PV systems have many useful applications and their demand is growing rapidly.

PHOTOVOLTAIC CELL CROSS SECTION





Solar panel cross section

Excited electrons flow through the silicon semi-conductor from the N-Layer to the P-Layer. They flow out the negative terminal, through the circuit, and back to the positive terminal. When a load is attached, the electrons are forced to do work (i.e. light a bulb).

Solar panel

Resources

For more information, check out these great resources on solar energy!

The NEED Project (www.Need.org)

http://www.need.org/needpdf/Photovoltaics%20Student%20Guide.pdf

http://www.need.org/needpdf/ExploringSolarStudent.pdf

The United States DOE Office of Energy Efficiency and Renewable Energy

http://www1.eere.energy.gov/kids/roofus/

http://www.eere.energy.gov/basics/renewable_energy/photovoltaics.html

Other cool sites

www.solarschoolhouse.org/

http://www.solar4rschools.org/

americansolarchallenge.org/

www.worldsolarchallenge.org/

http://www.energyquest.ca.gov/story/chapter15.html

http://science.howstuffworks.com/environmental/energy/solar-cell.htm

http://www.schoolgen.co.nz/se/

http://solardat.uoregon.edu/SunChartProgram.html

Solar Boats

http://original.solar-active.com/boat.htm

http://www.members.iinet.net.au/~gveale/solar/

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