Science Lab

SEED

Sun Tracker

Note: All of these activities need a sunny day with little or no cloud cover.

Each day, the sun rises in the east, moves across the sky, and sets in the west. Whenever the sun is shining on us, it is sending energy in our direction.

We can feel the heat from the sun, and we can see objects that are illuminated by the light from the sun as it moves across the sky. We should not look directly at the sun because of the risk of injuring our eyes. However, if we could get a solar cell to turn and look at the sun all day, then it would be receiving the maximum amount of sunlight possible and converting it into a more useful energy form – electricity.

In this activity, you will explore how to maximize the performance of a solar cell for the part of the world where you live. You will need the following from the Solar Energy SEEDPACK or from sources such as those listed in our Materials List on the web site (www.seed.slb.com/en/scictr/lab/sun_tracker/materials.htm).

- Solar cell backpack with two attached solar cells connected to junction box and *Power Out* cable
- Additional solar cell
- Voltmeter (Make sure it is turned off.)
- Two electric motors
- Two wheels to fit the electric motors
- One pair of alligator clip leads
- Coaxial adapter
- Coaxial DC power jack
- Stopwatch
- Protractor
- Transparent tape
- Three sheets of basswood or other lightweight wood each 30 cm by 10 cm by 5 mm (12 inches by 4 inches by one-fourth inch) with 1.25 cm (one-half inch) diameter hole
- Wooden block with 1.25 cm (one-half inch) hole and wooden dowel 1.25 cm (one-half inch) diameter 30 cm (12 inches) long for constructing sundial
- Tape measure
- Magnetic compass

Optional equipment for automated solar tracker (not included):

- GoGo board
  http://padthai.media.mit.edu:8080/cocoon/gogosite/home.xsp?lang=en
- Serial cable
- Two photo sensors
- Connecting posts
- Alligator clip leads
- GoGo Monitor software available as a free download from
  http://padthai.media.mit.edu:8080/cocoon/gogosite/home.xsp?lang=en

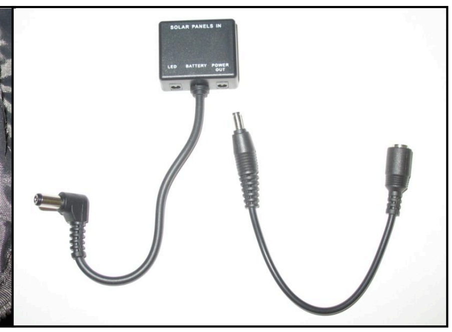
What To Do

If you place a solar cell flat on the ground and leave it there all day, what will its electricity production look like over time? Will its output change as the sun travels across the sky from east to west?

Set up a solar cell by doing the following.

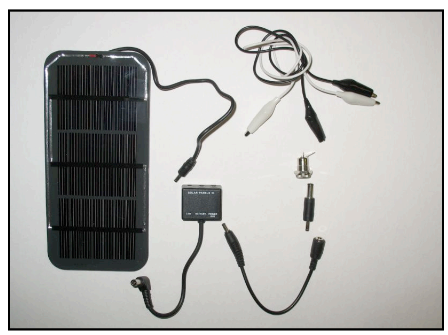
1. Unzip the backside of the solar cell flap of the backpack. Unplug the backpack junction box and the *Power Out* cable. Remove them from the backpack.

Junction box in backpack



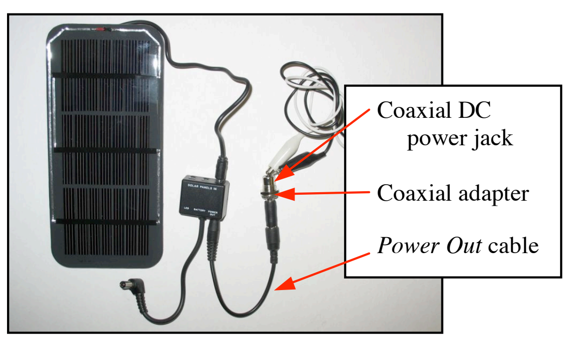
Junction box and *Power Out* cable

2. Collect the following items.
   - Solar cell
   - Junction box
   - *Power Out* cable
   - Coaxial adapter
   - Coaxial DC power jack
   - Two alligator clip leads

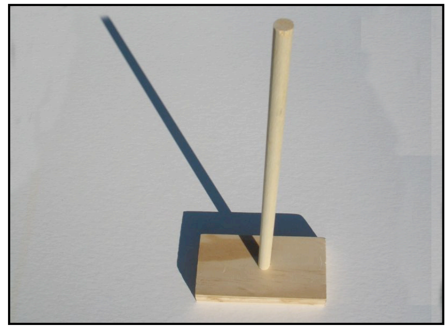


3. Connect the *Power Out* cable to the *Power Out* port of the junction box. Insert the coaxial adapter into the other end of the *Power Out* cable, and then attach the coaxial DC power jack.

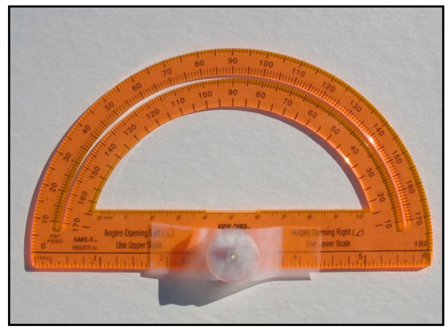
   Attach the ends of two alligator clip leads to the power jack, one to the central post and one to the side post.



4. Place the solar cell assembly on a flat place out of doors in the early morning hours of what looks like a relatively clear day. It is best to use an area that is not shaded during the day, so that you will not have to disturb or move the assembly. However, if you must move the cell assembly, be sure it is facing the same direction throughout the activity.

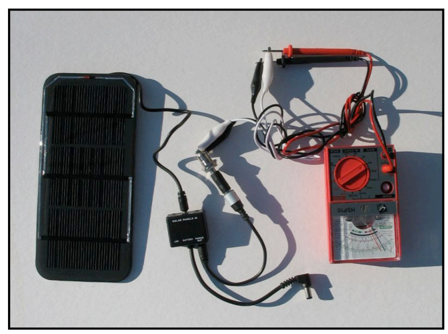


5. Assemble a simple sundial by inserting the dowel into the hole in the block of wood. Place this near your solar cell, but make sure that the dowel shadow does not fall on the solar cell.
6. Tape the magnetic compass over the central point of the protractor. You will use this to determine the direction of the dowel shadow at different times of the day.



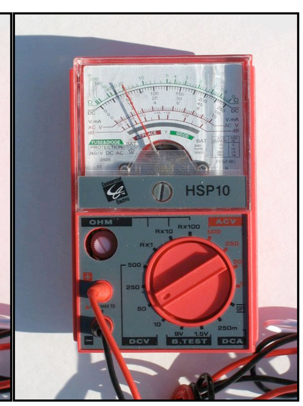
At hourly time intervals, you will need to do three things:

A. Connect the solar cell output alligator clips to the probes of a voltmeter to find the output voltage of the solar cell. Disconnect the voltmeter and turn it off between readings.

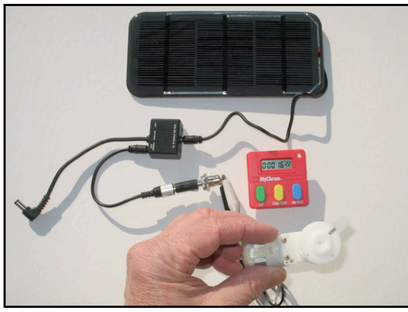


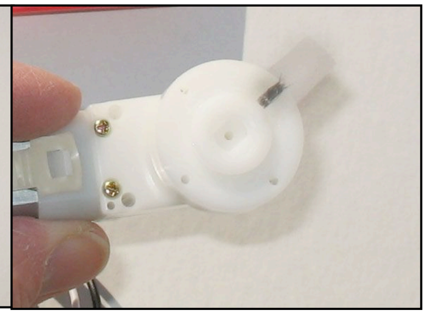
Note: Set the voltmeter scale so that the needle is not pushed past the end of the scale on either side. If the needle is pushed below zero, you will need to reverse the alligator clips on the voltmeter probes. If the needle is pushed past the far end of the scale, you will need to turn the red knob to change the scale. Most likely, the 50-volt scale will be the best to use.

Voltmeter with needle pushed past far end of scale

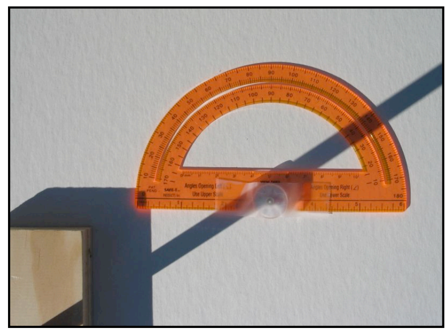


Voltmeter with proper scale setting





B. To the solar cell output alligator clips, connect a small DC motor with a wheel on its axle. Place a piece of tape on the wheel and make a mark on the tape for an indicator. Use the stopwatch to determine how long it takes for the motor axle to make ten rotations. In general, the faster the motor is turning, the higher the performance of the solar cell. (We recommend that you make at least three such measurements for each angle and then calculate the average time for each angle. This technique helps to reduce measuring errors.)



C. Measure the length of the shadow of the dowel, as well as the angle between the shadow and a line running north and south. In the photo below, the protractor has been turned so that its long side is aligned with the north-south line of the compass. The center of the compass is on one edge of the dowel shadow. The compass reading is made where that same shadow edge crosses the rounded part of the compass scale.

Record your measurements in the following table.

Time of day	**Solar cell electrical output (volts)**	**Time for ten motor axle rotations (seconds)**	**Length of stake shadow (cm)**	**Angle between stake shadow and north-south line (degrees)**

Based on the motor performance or the voltmeter reading, how would you describe the performance of your solar cell over the period of the day? Is there a period of time, maybe four or five hours long, where the solar cell performance is relatively and consistently high?

Graph the motor performance or voltmeter (vertical axis) versus the time of day.

Graph the length of the shadow versus the time of day.

Graph the angle of the shadow versus the time of day.

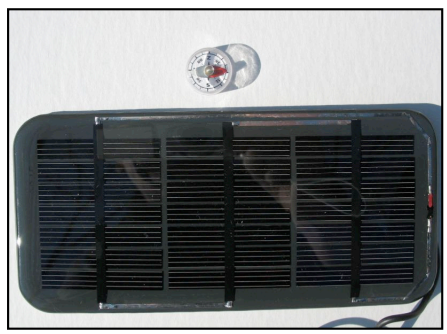
Do you see any relationships among the graphs?

Tuning the Tilt:
Adjusting for the Tilt of the Earth

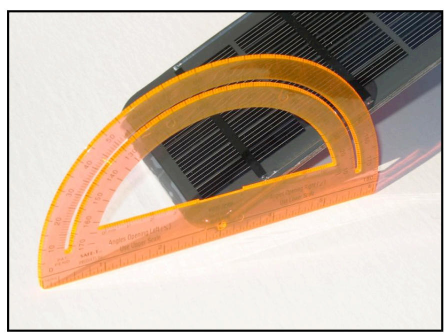
If you are located in the tropics, you see that the sun appears to follow a path that is nearly directly overhead. However, for locations north or south of the tropics (e.g., latitudes greater than 23.5 degrees), the sun never reaches a position that is directly overhead. Instead, it follows a path across the southern or the northern part of the sky.

How can you position your solar cell to take maximum advantage of the sun's energy if it does not go directly overhead during the day? In this activity, you will find a good general angle for doing this during the middle part of the day. [If you are located in the tropics, you can still do this activity, but the best angle for your solar cell will be horizontal, most likely.]

1. Using the same solar cell setup as in the previous activity, place your solar cell on a flat surface that the sun shines on during the middle part of the day. Orient your cell so that the long dimension points north and south.



2. Tape down the end of the cell that faces the area of the sky that includes the path of the sun. (For the northern hemisphere, you would tape down the south end, and for the southern hemisphere, the north end.) The tape creates a hinge so that you can incline your solar cell to the sun at a variety of angles.



3. Use the same solar cell hookup method as the previous activity. With the solar cell horizontal at an initial angle of 0 degrees, attach a voltmeter to the output alligator clips and record the voltage for the angle of 0 degrees in the table on page 6.

4. Disconnect the voltmeter and connect the electric motor with a mark on the wheel. With the stopwatch, measure how much time it takes for the motor axle to make ten rotations. (We recommend that you make at least three such measurements for each angle and then calculate the average time for each angle. This technique helps to reduce measuring errors.)

   Repeat these measurements for other angles of tilt and record your results in the table below.

Angle	**Solar cell electrical output (volts)**	**Time for ten motor axle rotations (seconds)**
0		
10		
20		
30		
40		
50		
60		
70		
80		
90		

For our results taken around noon at a latitude of about 37 degrees north, the voltage did not change very much with the angle. However, the time for ten motor axle rotations showed a definite pattern, with slow turning at tilts of 0 degrees and 90 degrees, and faster turning at a tilt of about 40 degrees.

Thus, for our location and time of year, the optimal angle of inclination for a solar cell would be about 40 degrees through the middle portion of the day.

This means that if we were to set up a stationary solar cell, we could maximize the output by tilting it up at an angle of 40 degrees from the horizontal.

Solar Tracker

But what about a movable solar cell? If we could configure a solar cell so that it faces the sun continually as it moves across the sky from east to west, we could get the most electrical energy possible. One way to do this, of course, is by hand. However, keeping a solar cell facing the sun throughout the day is not a very efficient use of a person's time. Going outside to a solar cell every hour to turn it toward the sun might be possible, but this would still require human attention.

What we need is a tracking system that would automatically keep the solar cell facing the sun throughout the day. You already know something about the movement of the sun and the various local angles for best performance. You are now ready to design and build an automated system of your own, using a single motor.

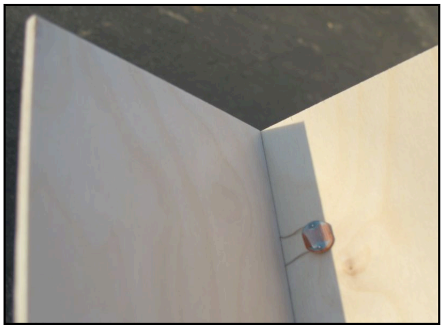
The system would probably include a frame on which a solar cell could be mounted. The frame would have to move so that it could face the sun as it travels across the sky during the day. The frame could be driven by an electric motor that turns on and off in response to the movement of the sun.

Because there are many different ways to approach this activity, we are keeping it completely open-ended. However, we will offer a few ideas and suggestions.

Perhaps you could use a GoGo board and a photo sensor (see list of optional materials) to control the solar cell tracking system. For example, if the photo sensor is in shadow, then it could turn on the motor until it was in sunlight once again. If the motor is attached to the frame holding the solar cell, then the solar cell could be moved to face the sun.

Photocell in sun

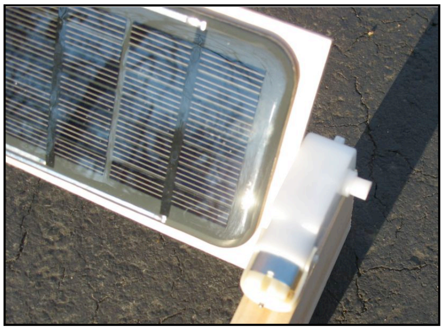
In the photographs here, a photo sensor is mounted on the bottom part of an L-shaped channel made with two thin sheets of wood. This could be part of the solar cell frame and used in a GoGo program. As long as the photo sensor is in the sun, nothing happens. However, when the sun moves across the sky enough to cast a shadow on the photo sensor, then a motor moves the frame until the photo sensor is in the sun once more. This could have the effect of keeping the solar cell facing the sun as it moves across the sky.



Photocell in shadow

As you know, if you live north or south of the tropics, the path of the sun does not go directly overhead. You would probably need to track the sun across the sky with a technique like the one shown in the photograph on the right. Set the solar cell to the optimal angle of tilt you found in Tuning the Tilt. Then use the motorized wheel to roll on the ground and turn the cell horizontally from east to west during the day.

If you live in the tropics, you know that the path of the sun goes directly overhead, or nearly so. You could use a technique like the one shown in the photograph on the roght. The solar cell and its frame are mounted directly on the axle of the motor. The cell could face east in the morning. As the day goes on, the motor axle could rotate, turning the cell upward in the middle of the day, and then downward toward the west later in the day.



Putting It All Together

As a final project, use two motors to design, build, and operate an automatic solar tracker that incorporates both techniques shown above. One motor would swing the solar cell horizontally from east to west during the day, and another motor would tilt the solar cell vertically.

Troubleshooting Guide

Q: I am having difficulty with the voltmeter readings. What can I do?

A: First, make sure that the voltmeter needle is not pushed off the scale on either side. Turn the red knob to adjust the scale until you find one in which the voltmeter needle comes to rest somewhere between the two sides. Next, look at the number next to the indicator of the red knob. Find that same number on the right hand side of the voltmeter. Take your reading from that set of numbers.

For example, in the photographs here, the red knob is set to the 50-volt scale. The needle reading is about 10 volts. The needle is above the 10 in the 0-to-50-volt range of numbers on the voltmeter dial.

Q: When I connected the motor to the solar cell in the early part of the morning, nothing happened. Later in the day, however, the motor went around. Am I doing something wrong?

A: In the morning hours, there is often not enough light energy to start the motor turning. If you give the wheel a small turn with your hand, this might be enough for it to start and keep going. In general, the motor turns more slowly in the morning hours than in the middle of the day.

Q: I cannot get any reading with the voltmeter, no matter what scale I set it to. What might be wrong?

A: The voltmeter battery might be run down. Check the voltmeter battery by using the voltmeter to test another battery that you know is good. Turn the red knob of the voltmeter to the 10-volt scale. Place the black probe on the bottom or negative side of the battery, and the red probe on the top or positive side of the battery. If you are not getting any reading, then the voltmeter battery should probably be replaced. You can prolong the life of your voltmeter battery by turning the voltmeter off whenever you are not using it.