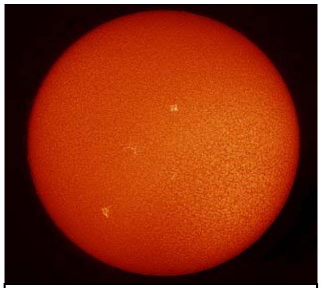
Solar Energy – Harnessing the Power of the Sun



Telescope: Borg 45ED II
Filter: Solarmax 40/BF10
Camera: Nikon D50
W. Glogowski

Overview:

Did you know the Sun is star? The Sun is actually an average star. There are other stars which are much hotter or much cooler, and stars that are much brighter or fainter. However, since it is the closest star to the Earth, it looks bigger and brighter than any other star in the sky. It is so bright that it is the only star we can see (without the aid of a telescope) during the day. The Sun is mostly made up of the elements hydrogen and helium.

The Sun is neither a solid nor a gas but is actually a plasma. Plasmas are complicated to understand but at the surface of the sun the plasma is gaseous, but as you travel deeper into the Sun's center it gets denser. The center of the Sun is usually referred to as its "core." The energy produced in the Sun's core powers the Sun and produces all of the heat and light that we receive here on Earth. All of the energy that we detect as light and heat on Earth originates from nuclear reactions deep inside the Sun's high-temperature core. This core extends about one quarter of the way from the center of Sun where the temperature is around 15.7 million kelvin (K) or about 28 million degrees Fahrenheit.

We can use the energy from the Sun as a practical source of energy for heating our homes, heating water or even cooking. The challenge is to find ways capture and concentrate the energy from the Sun so we can use it efficiently. All of us have probably experienced sitting in the bright sunlight wearing a pair of dark jeans or a dark tee-shirt and feeling incredibly hot. The most efficient way to use the heat from sunlight is shine lots of sunlight onto a dark surface. Dark surfaces absorb most of the Sun's visible light that falls upon them, and reflect very little. Visible light that is absorbed this way usually causes the dark-colored surface to warm up. Of all colors, black is able to absorb the most light, and produce the most heat.

National Science Standards that are addressed in this activity

	Science Standards				Math Standards			
Content Standards	Science as Inquiry	Physical Science	Earth and Space Science	Science and Technology	Geometry	Measurements	Data Collection	Data Analysis
	X	X	X	X	X	X	X	X

Materials for each group of 4 students:

- ☐ Corrugated cardboard (large flat sheets work best as apposed to small boxes)
- ☐ One roll of duct tape or clear packing tape.
- ☐ Black tempera paint
- ☐ Paint brush
- ☐ White glue (16 oz)
- ☐ One roll of Aluminum foil (heavy duty)
- ☐ Meter stick or other metric tape measure
- ☐ Oven thermometer
- ☐ Felt tip marker
- ☐ Sunglasses
- ☐ Shredded paper or insulation

Optional Items

- ☐ Medium aluminum foil cake tin
- ☐ Oven mitts
- ☐ 1 medium transparent oven bag

Teacher Item

- ☐ Sharp Utility Knife

Objective:

Students will build a solar oven that will collect sunlight and warm water or a pre-cooked hotdog to a temperature of 160 degrees Fahrenheit or 72 degrees Centigrade. From this they will learn about solar energy, radiant heat, and absorption of heat, geometry, data collection, data analysis and technological design.

Procedure:

1. Introduce this activity by reviewing the basic physics of the Sun.
2. Discuss the geometry of the Suns path across the sky.
3. Discuss ways which you can reflect sunlight.
4. Discuss the difference between absorption and reflection of energy
5. Discuss how someone might concentrate sunlight into a very small spot.
    a. If your students are old enough you may want to explain the properties of a parabolic surface (see references at the end).
    b. If your students are young and do not have the background to understand the geometry of a parabolic surface lead them in a discussion of why small satellite dishes (like Direct TV and Dish Network) collect a signal from a satellite orbiting the Earth and bring programming into their homes.
6. Explain to the students that they will be building one of two types of solar collectors: 1) a parabolic collector and 2) a more traditional solar box oven. They are to use the plans to build each collector and they are test each collector making careful measurements of time vs. temperature on how long it takes to heat up to 160^{o}F.
7. Once they have collected their data have the students brainstorm ideas for improvement and construct a second collector. Ask them to retest the second oven and journal about the changes they implemented and what if any outcomes the changes produced.

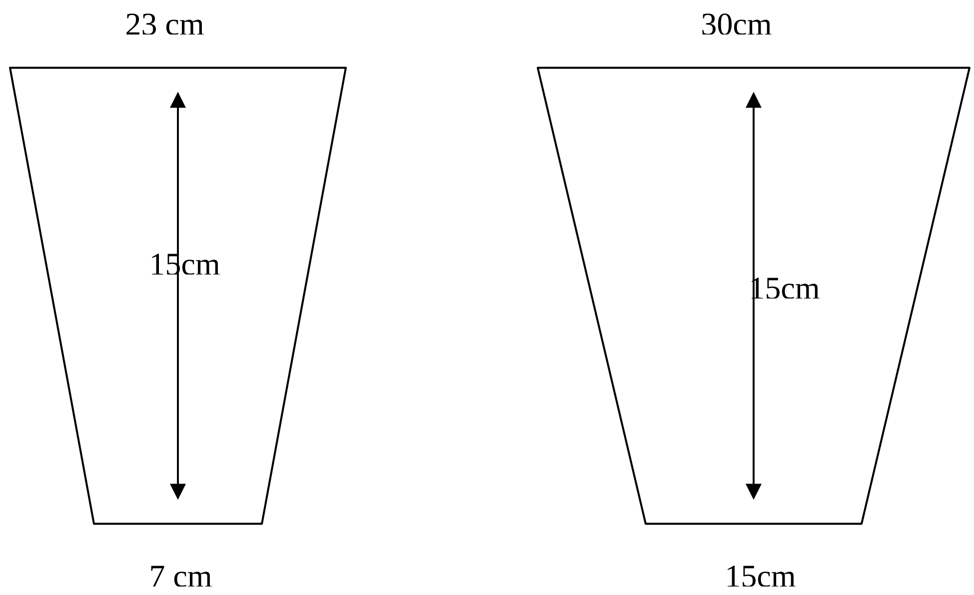
Assessment:

The students' work can be assed using the following rubric:

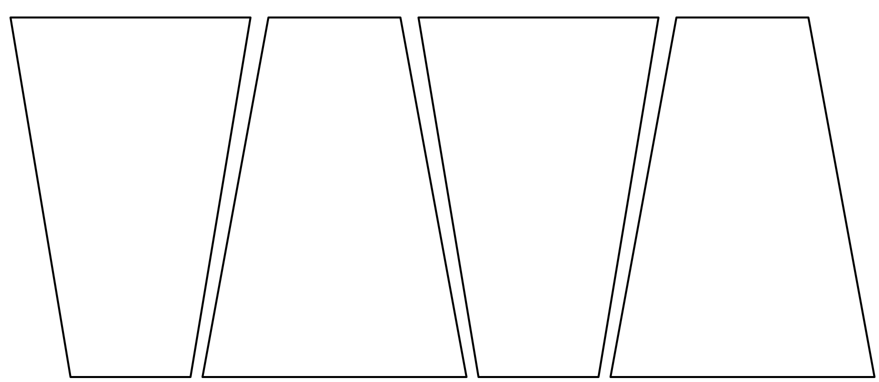
Points	Criteria
4	- Model is assembled correctly and neatly - Time vs. Temperature data table is carefully and neatly completed - Time vs. Temperature is graphed as a scatter plot correctly - Time vs. Temperature graph has a line of best fit drawn - A summary of observation been entered into their journal.
3	- Model is assembled correctly but not neatly - Time vs. Temperature data table is completed but not organized neatly. - Time vs. Temperature is graphed but the axis is labeled incorrectly or increments are not consistently spaced. - Time vs. Temperature graph has a line of best fit that "connects the dots" and does not represent a smooth line. - A summary of observation been entered into their journal, but it is chronologically unorganized. .
2	- Model is assembled correctly but is not functional - Time vs. Temperature data is written down but not organized in a data table - Time vs. Temperature is not graphed correctly. - Time vs. Temperature graph has no line of best fit. - A summary of observation been entered into their journal, but is not organized.
1	- Model is assembled incorrectly and is not functional - Time vs. Temperature data is not organized. - Time vs. Temperature is not graphed. - A summary of observation is incomplete or missing completely.

Traditional Solar Cooker Construction Plans

1. Cut two of each.



An easy way to cut the shapes is to "book-end" them into a pattern as follows on one large piece of cardboard.



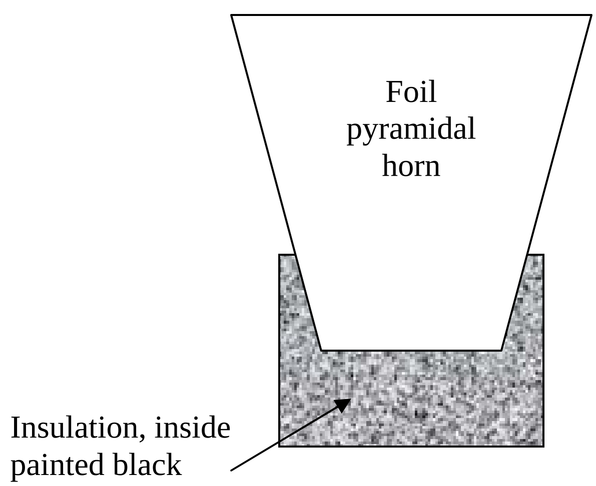
2. Glue "Heavy Duty Aluminum" foil on the cardboard pieces. If you use the book-end approach first glue down the foil on the back side of the template, allow it to dry and then cut through the cardboard and foil with a sharp utility knife in one step.

3. Once you have cut out the foiled pieces match them as shown in the picture and tape them together.

4. Once taped together they should from a pyramidal horn shaped structure

5. Assemble your second smaller box and place the pyramidal horn into the box and tape it in place

6. The bottom of the small second box should be lined with shredded paper and painted black inside with the Black tempera paint



7. To prepare the cooking chamber, take a medium foil cake pan and paint the inside of the pan black. Once the paint is dry line the pan with a medium transparent oven bag and place your item to cook inside the bag along with your oven thermometer.
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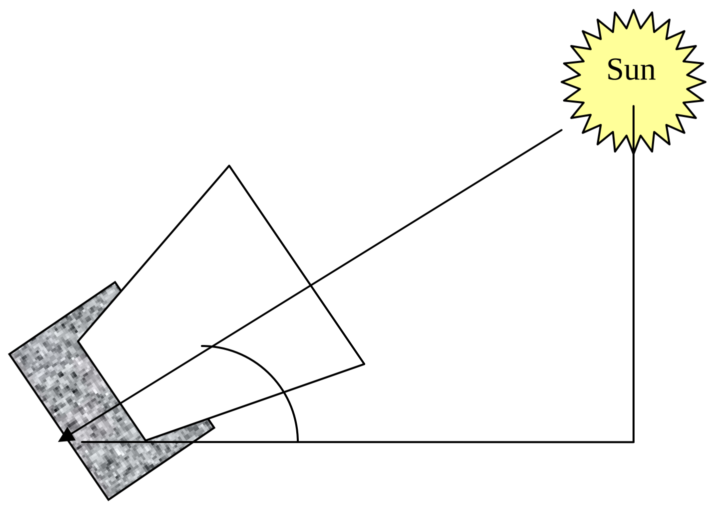
Pointing the Solar Cooker

You may want to allow your students to do the following as an inquiry extension.

1. Ask your students now that you have the oven made, how should they position it so they collect the most solar energy. You should not be surprised to hear many of them respond to point it at the Sun. If you choose to, you may go into a lengthy discussion about:
   a. What is the best angle to use
   b. Dose this angle change throughout the day?
   c. Dose this angel change throughout the year?



Angle theta may be
measured and recorded

Data Collection

1. As soon as they have positioned the solar cooker remind your students to begin to collect data (time vs. temperature). They may ask you how long should they wait between readings. It has been my experience that if you are using an oven thermometer one reading every 2 minutes is sufficient. You may adapt this activity by using a temperature probe and in that case have dynamic collection of time vs. temperature. Your oven should easily reach a temperature of 200 degrees within 30 – 40 minutes.
2. Ask your students to prepare scatter plots of time vs. temperature and draw a line of best fit through the data points. You should see a linear relationship until the unit reaches its maximum cooking temperature.

Extension

If you also have your students track the Sun with the cooker they can make measurements of the angle they use, the amount of East to West movement needed to keep the Sun's rays directly in the cooker

Parabolic Solar Cooker

Overview:

Parabolic surfaces have unique reflective properties. As light strikes a parabolic surface each incident rays is reflected back off the surface to one discrete point called the focus. This property is used in making reflective mirrors for light telescopes and radio telescopes. It is also the property that is used to make a parabolic solar cooker.

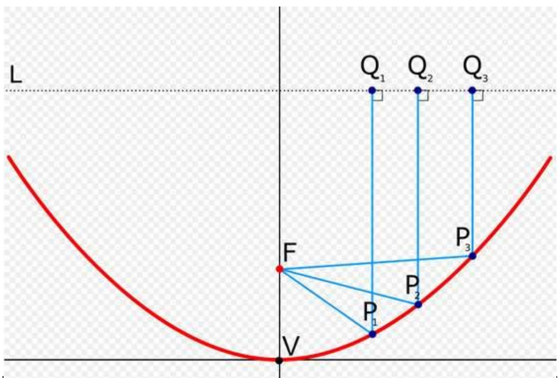


Figure generated with Mathematica ©
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Think of each ray of sunlight (Q1, Q2, Q3) striking the surface of a parabola and being reflected to the focus.

WARNINNG Parabolic cookers can reach temperatures of over 400°F at the focus!

The construction of parabolic surface can be daunting and the mathematics will not be covered here, but a simple parabolic drawing tool can be constructed that will enable you and your students to make a variety of parabolic dishes.

Making the parabolic drawing tool

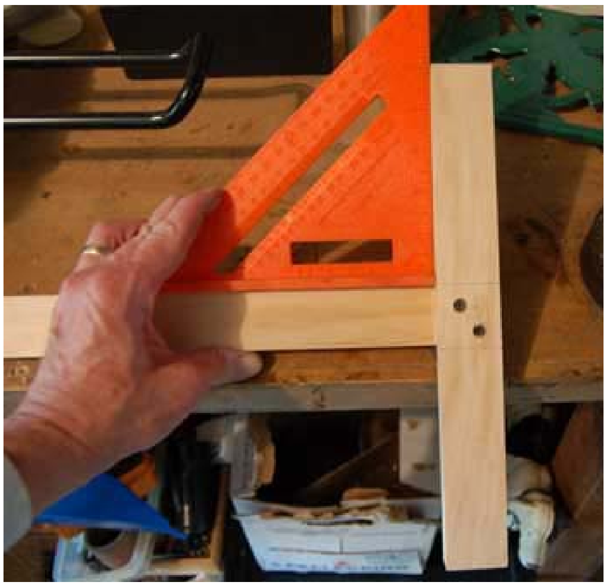
Materials:

- ☐ 1 piece of 1 x 3 inch clear pine 6 feet long (enough for two tools)
- ☐ Four wood screws
- ☐ Carpenters glue
- ☐ Right angle square
- ☐ Hand held drill
- ☐ 1/8 inch drill bit

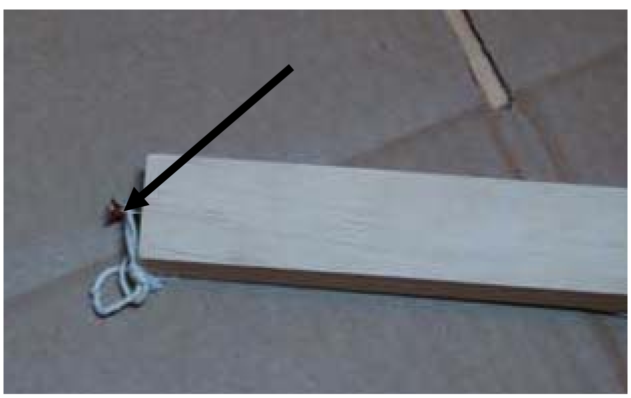
- ☐ 1- 3/8 inch washer
- ☐ Length of non-nylon string
- ☐ Hand saw to cut wood

Construction Procedure

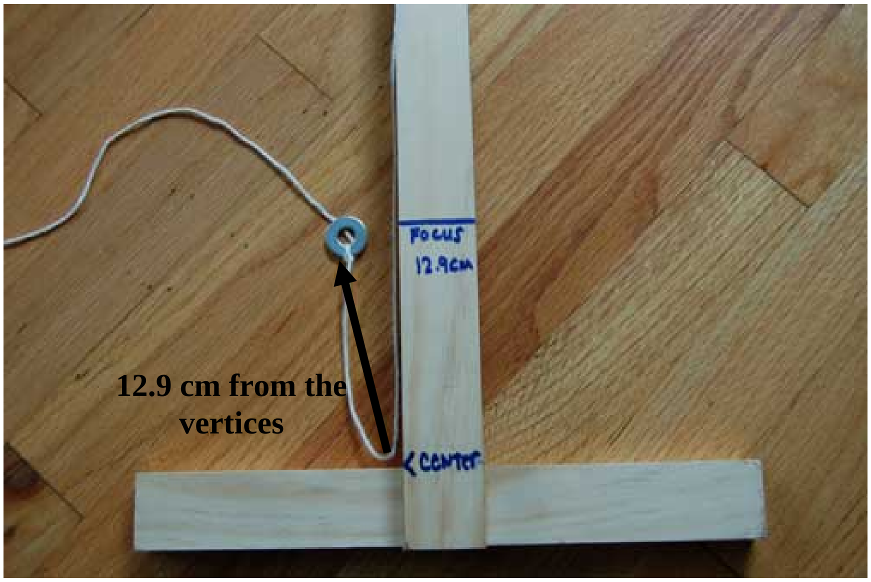
1. Cut the 1 x 3 pine into two pieces one exactly 12 inches long the other 24 inches long.
2. Pre-drill two holes into the 12 inch long pieces as shown. Glue and screw the 12 inch piece as shown, being very careful that the two pieces area at exactly 90^0. Use the right angel square to assure this angle is exact.



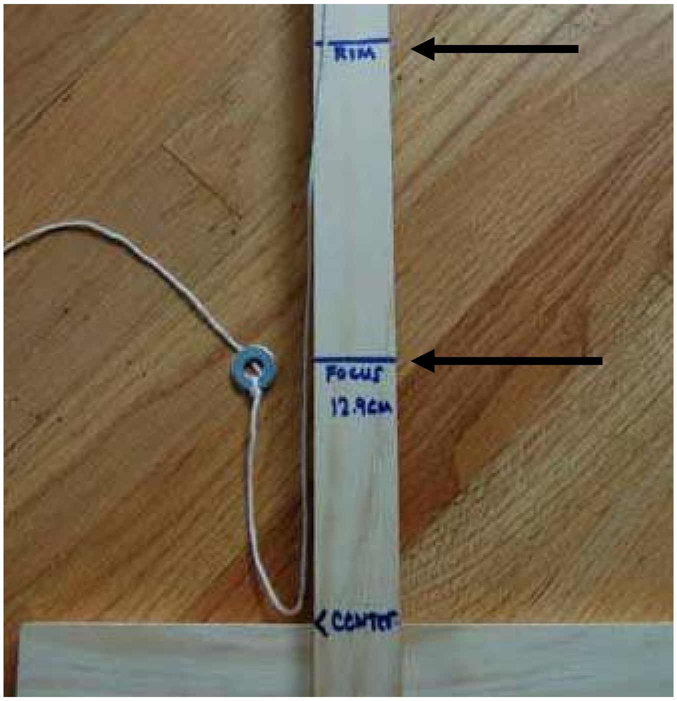
3. Drill a pilot hole on the top of the long 24 inch piece and drive a screw partial into the top as shown



4. Attach your non-nylon string by making a loop and cut the sting to approximately 36 inches. Attach a washer at the free end exactly 12.9 cm from the vertices of the tool as shown



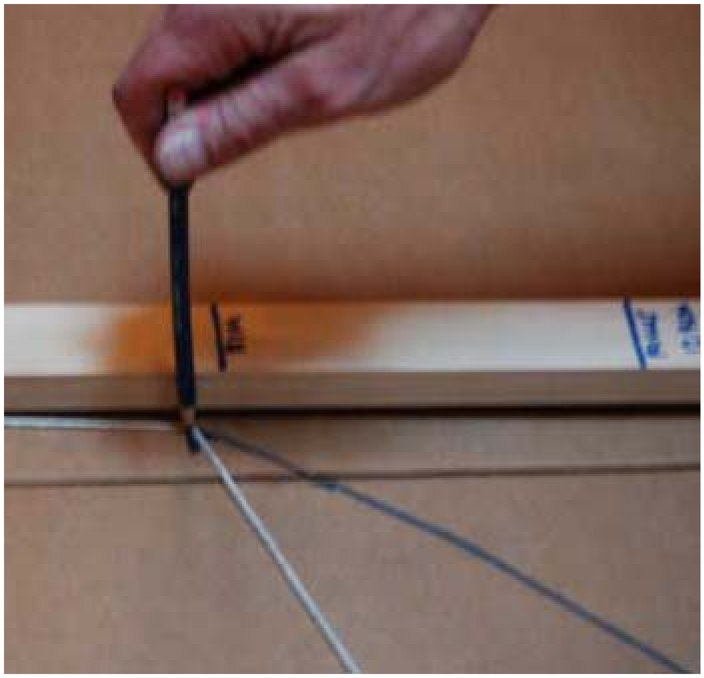
5. Label the tool as shown: “Focus” is where the washer meets the long 24 inch upright, and “rim” is twice the distance of the focus.



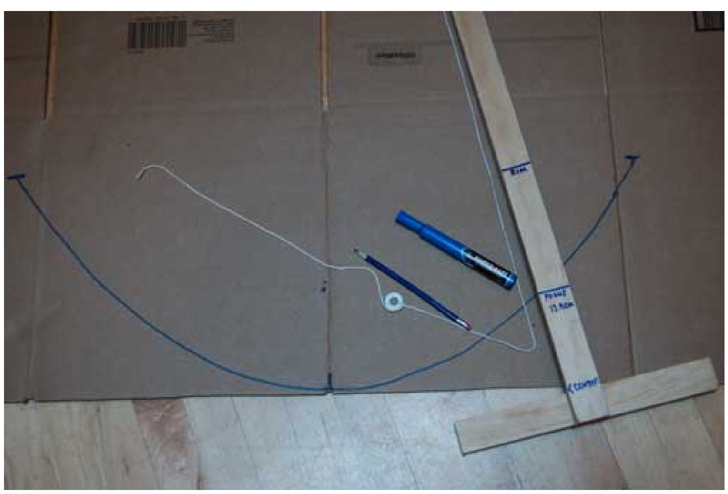
Using the parabolic tool

1. Place the cardboard that you plan to use on a flat surface and place the tool on the edge of the cardboard in the center. Hook the washer with a nail or sharp tool to the focal point. Place a pencil at the vertices and pull the tool along the bottom of the cardboard being sure to hold the pencil firmly at the edge of the tool. As you move the tool the pencil will trace out a parabolic curve that is mathematically correct for the focus that you choose.

2. Continue to trace with the pencil until you reach the "rim" Repeat the process for the other side. To ensure you have an accurate parabolic curve you may want to trace the curve several times and make sure you are getting the same profile.



3. When you are done darken the line with a marker



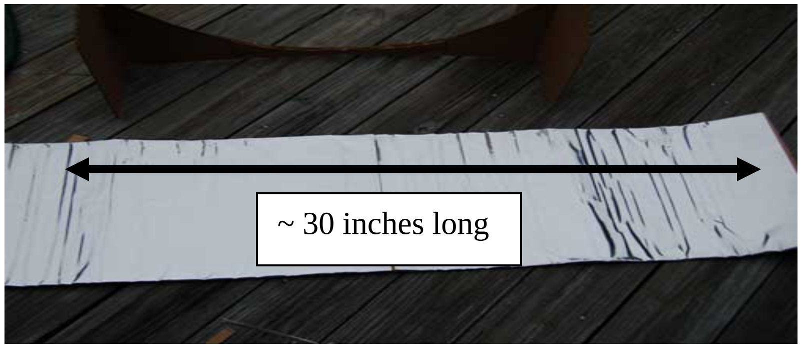
4. Once you have darkened the line you can cut it out with a sharp utility knife and make two cardboard bookends to hold the parabola in shape.

Extension:

You can use the cardboard as a template to cut out a plywood form and then you will have a more permanent parabolic surface. With care you can get amazingly accurate results and even construct an entire parabolic dish!

http://home.germany.net/100-441770/work02.jpg

5. Cut a strip of cardboard approximately 12 inches wide and 30 inches long and glue foil to the board to create a reflective surface.



6. The cardboard/foil laminate will be stiff so you will need to pre-roll the board into a circular shape that will conform to the parabolic form. If you are using corrugated cardboard the natural corrugations will allow you to create a relatively sooth surface.

7. Once the cardboard is formed form into the parabolic form and tape it in place. While this is not a full parabolic surface the collecting power of the surface will be greatly amplified at the focus.

Pointing the Parabolic Dish Cooker

This procedure is the same as pointing the solar oven. Unfortunately it is harder to actually cook something with this design, but it is easy to mount an oven thermometer or temperature probe at the focus and see how quickly the parabolic surface focuses the light energy from the Sun.

Extension

1. You maw want to ask your students to compare time vs. temperature graphs of the parabolic surface vs. the solar oven and determine which device heats up quicker
   a. Ask your students to prepare a graph of both devices on one graph and have them journal their observations.
2. Ask your students to make a prediction of what would happen if a second reflective surface as added 90^o to the first? What would be the maximum temperature at the focus? How much quicker would the device reach maximum temperature? Then have the class build a working model and perform proof of concept test.

WARNING: If you plan to make a full parabolic surface cooker the temperature at the surface (if the dish is pointed correctly) can reach up to 400^0 F!

Journal Prompts

a. Look back at your solar cooker. Did your observations from the virtual investigation help you to make decisions about how your cooker would measure up in real life?

b. What are the limitations of using a solar cooker? Describe how they may be overcome.

c. What could you do to improve your design?

d. Using what you learned, what exterior and interior colors and materials would you want in a car if you lived in a hot sunny climate? What colors and materials would you pick if you lived in a cold sunny climate?

e. How might you use the principles of solar radiation in other parts of your life or home?

If you have any question, pleases feel free to contact me at wglogowski@ameritech.net