1. Solar Oven

1.1. Background

(Adapted from: greenlearning.ca) Most people know that the sun is a great source of energy; however, when most people think of the solar energy, they think of electricity and solar panels. In this experiment you will see another side of “solar power,” that is, solar thermal power. You are familiar with the idea that the sun heats the Earth, with the help of the greenhouse effect, so you know that the sun radiates a lot of heat energy. Solar thermal energy has been experimented with since the 1800's, and since 1892, millions of people have reaped the benefits of this thermal energy in the form of solar heated water. In more recent years, scientists have perfected the use and collection of solar thermal energy to produce electricity, heat homes, and purify water. **Figure 7** shows a solar thermal collector that is used to heat a fluid, such as oil or steam, in order to power a heat engine and produce electricity.

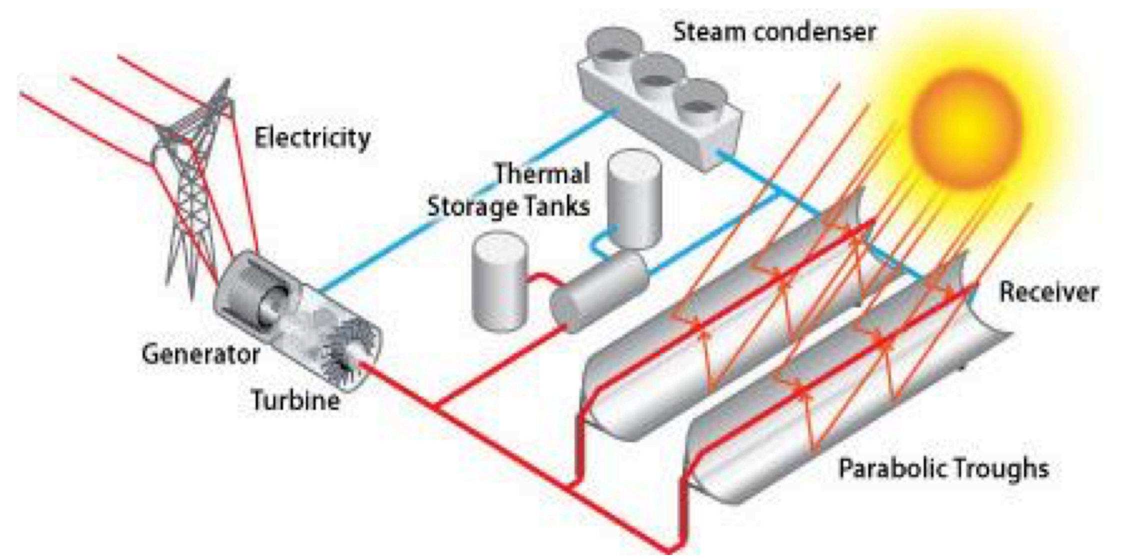


Figure. Solar thermal power plant

One of the more interesting uses of solar thermal energy is solar cooking. Near the end of the 19th century, a British Soldier in India received the first patent for a solar cooker design. Although there is a long history behind solar ovens, many of the designs we see today came about in the 1950's when the United Nations funded research for solar cooker designs in order to alleviate some reliance on plant life for fuel. The conclusion of the numerous studies was that with a properly constructed solar cooker, food could be cooked thoroughly and nutritiously. In order to test the sun's thermal power, you will be constructing a solar cooker, performing several tests, collecting data and analyzing the design.

1.2. Solar Oven Activity Guide

Adapted from reference 4

Who: Group of 4 students
What: Build a solar oven and bake cookies. The purpose of this activity is to learn concepts of solar energy and heat transfer.
Where: Classroom and outdoors
Time: 4 hours

Supplies:

Item (Consumables)	Quantity	Check out	Check in	Notes
Large cardboard box	1		NA	
Small cardboard box	1		NA	
Transparent oven bag	1		NA	
Sunglasses	4		NA	
Cookie dough	6 cubes		NA	
Shredded paper	small box		NA	
Aluminum foil roll	1			
Aluminum foil bake tin	1			
Multimeter thermocouple	1			
Duct tape roll	1			
White glue bottle	1			
Plastic cup	1			
Utility knife	1			
Yard stick	1			
Oven mitts	4			
Cupcake wrappers	6			

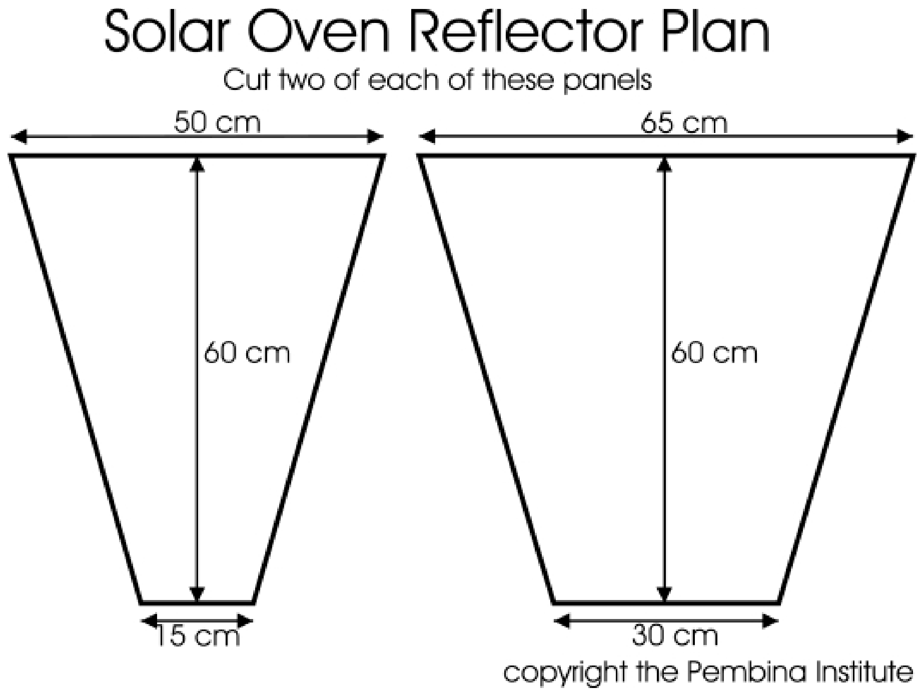
Objectives:

- Learn basic principles of solar thermal heating and heat transfer.
- Measure the temperature at various points in time and calculate heat transfer rates.
- Explore the effects of shade on temperature and rate of heat transfer.
- Construct heating curves and predict effects of certain design alterations.

SAFETY NOTES:

- **Eye Hazard** - Use sunglasses when working with shiny materials in sunlight.
- **Burn Hazard** - The solar oven design you are using is capable of reaching temperatures of 400 degrees Fahrenheit! Use extreme caution and oven mitts or gloves to prevent burns when handling the contents of the oven.
- **Cut Hazard** – Use utility knife carefully and as directed by activity leader

Procedure:



A. Prepare the Reflective Panels

1. Using a meter stick and pen, draw the outlines of the reflector segments on your cardboard. Use the measurements on the blueprint template.

2. Using the utility knife, carefully cut out the 4 cardboard segments. Use a ruler or straight-edge to help guide your cuts. **CAUTION: Utility knives can be dangerous.** Extend the blade only as far as necessary to cut through the cardboard. Use some scrap cardboard or wood under the material you are cutting to avoid damaging the tabletop.

3. Remove the top from the white glue bottle and pour approximately 100 ml (~ 1/4 cup) into the plastic container. Add 4 tablespoons of water to the glue and stir thoroughly. This will make the glue thinner and easier to spread evenly.

4. Carefully unroll enough aluminum to completely cover one section. Keep the foil as smooth and flat as possible. Wrinkles and creases in the foil will reduce the efficiency of the reflector. If the cardboard is wider than the foil, use two pieces of foil and plan to join them near the middle.

5. Apply a thin layer of white glue over the entire surface of the cardboard. Be sure to spread the glue right to the edge of the cardboard. Use the flat edge of a piece of scrap cardboard as a squeegee to spread the glue out evenly.

6. Before the glue dries, place the foil on the cardboard shiny side up, and smooth it down over the entire surface. Try to press out any wrinkles, bubbles, or creases in the foil. If your foil gets badly wrinkled during the gluing process, tear it off and try again with fresh glue.

7. Using the utility knife, trim the foil so that it is flush with the edge of the cardboard all around. Set the panel aside to dry.

8. Repeat steps 4 through 7 for the remaining sections.

B. Join the Panels

1. Cut 8 pieces of duct tape 60 cm long and set them aside (stick them to the edge of the table for easy retrieval).

2. Arrange the segments as shown in the photo below, foil side down, wide sections alternating with narrow ones. The narrow end of each should point toward you.

3. Carefully position the first two panels, keeping a 2 mm space between them. Position one of your 60- cm strips of duct tape over the joint between the panels. Press it onto the joint, being sure it sticks securely to both panels over its full length.

4. Join the third and fourth panels as in step 3 above.

5. Carefully flip the joined panels over on the table. This may require two people. Reinforce the joint between each panel using another

strip of duct tape.

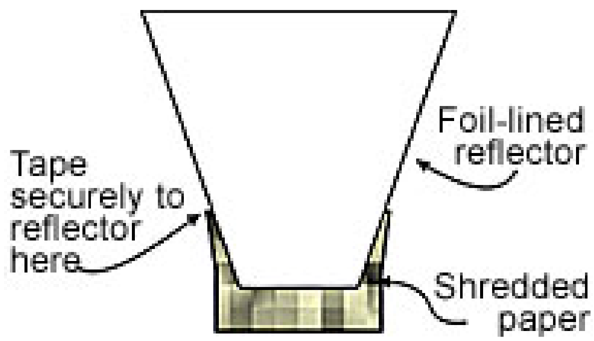
6. Stand your reflector up (foil side in), bringing the edges of the outer two panels together. Have your partner hold the reflector in position while you add the last piece of duct tape.

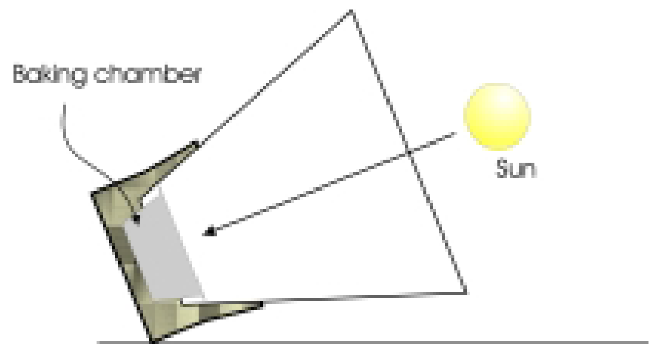
7. Finish the last joint inside the reflector by applying the remaining piece of duct tape.

C. Add the Insulated Box

1. Using duct tape, fasten the cardboard box securely to the bottom of the reflector by its flaps. Be sure the box is centered. Add a few strips of duct tape to the corners to make the assembly more rigid.

2. Stuff shredded paper into the gaps between the box and the reflector. Leave a little of the paper on the bottom of the box, as shown in the illustration.





E. Test the Solar Oven

The solar oven is now ready to be tested. If it is a sunny day, you can warm up your oven in preparation for its first cooking job.

1. Place cookie dough squares into muffin tin and then into the tin baking pan.

2. Place the baking tin into the transparent plastic oven bag, making sure to slip in the thermocouple thermometer as well. Arrange the bag so that the plastic forms a smooth, unwrinkled window over the baking chamber.

3. Press the baking chamber tightly into the bottom of the reflector.

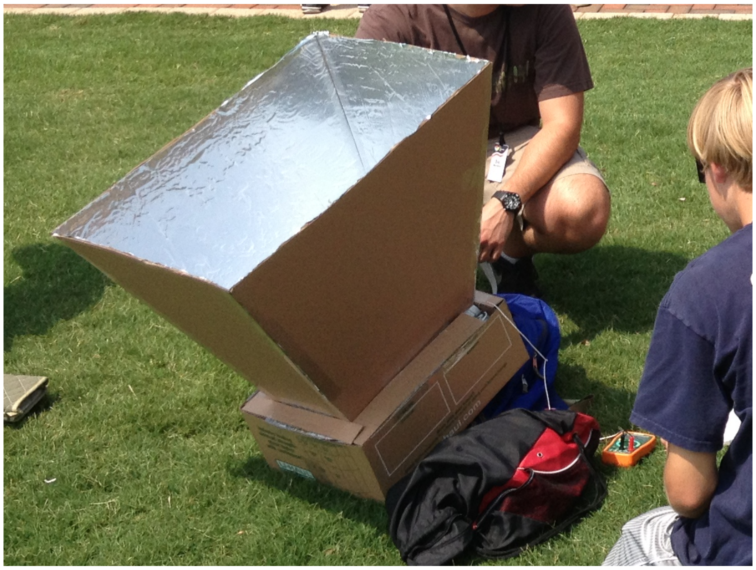
4. Outside, and with your sunglasses on, arrange your cooker so that the cooking chamber is fully illuminated by the sun. The diagram below shows you how to orient the reflector to get the most heat from the sun. You will need to prop the reflector up on some books, bricks, or other objects to keep it at the right angle.

5. If the day is sunny, clear, and warm, the temperature inside the cooker should begin to reach 100 degrees C or more within minutes. Allow the cooker to reach its maximum temperature and record this. If your cooker reaches 100 degrees C, you can use it for heating foods. If it gets to temperatures of 175 degrees or higher, it will begin to bake your cookies.

F. Measurements

Record temperatures in oven and determine heat transfer into and out of oven.

1. The oven will heat up very quickly over the first few minutes; make sure to record the temperatures at the intervals shown in the table on the next page. You will also need to record the temperature of the surroundings.



2. The other test that you will perform will explore the effect of shade on the oven. You may choose to do this at any time while you are baking your cookies. Use something (your workbook will suffice), to cover about 25% of the opening of the oven; record the temperature of the oven, not the surroundings, at 15 second intervals for one minute. Remove the shade and allow some time to pass for the oven to heat back up again. Repeat this process again, this time shading about 75% of the oven.

The cookies should take about 40 minutes to bake after the oven has heated up. In total the experiment should take about an hour (the cookies may not turn brown). Remove the cooking pan **with oven mitts**.

Start calculating the heat transfer rates when you have collected all the necessary data. Plot the rate of heat transfer and temperature of the oven as a function of time on the provided graphs.

Solar oven data:

Time (min)	Temperature (°F)		Heat Transfer Rate (W)
	Oven	*Surroundings*	
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
12			
14			
16			
18			
20			
25			
30			
35			
40			
45			

% Shade	Time (sec)	Temperature (°F)
25	0	
	15	
	30	
	45	
	60	
75	0	
	15	
	30	
	45	
	60	

Heat Transfer Rate:

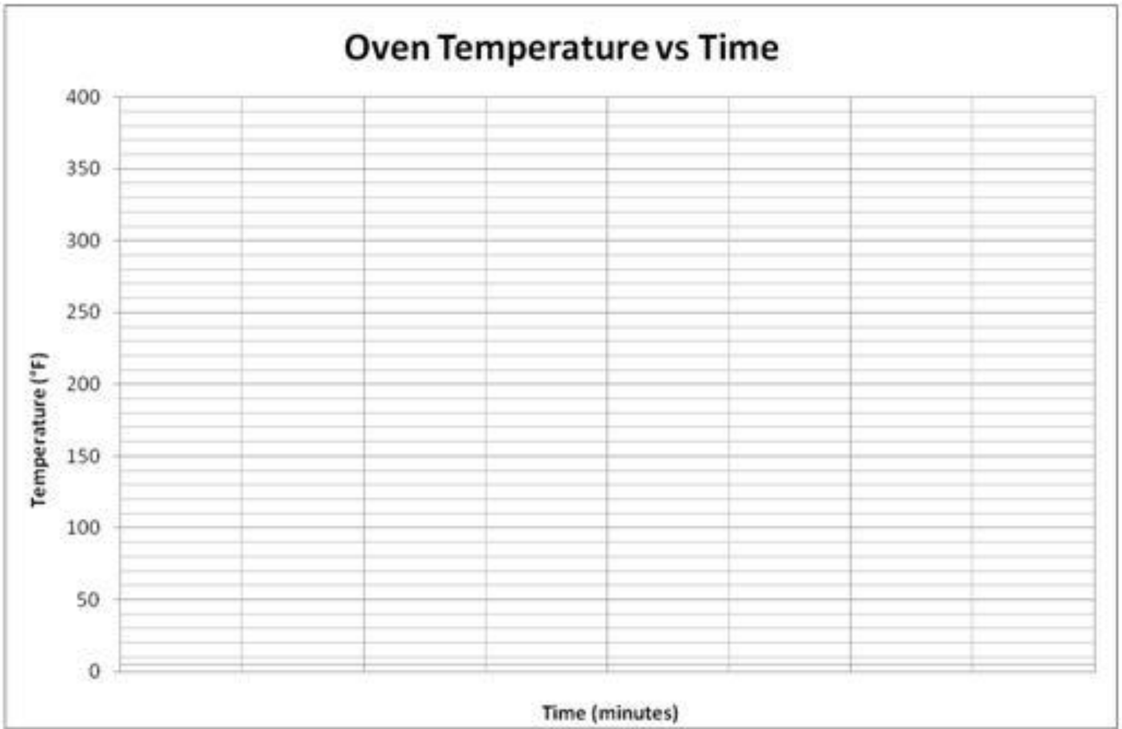
$$q = kA\frac{\Delta T}{L}$$

k=.2 (.15 to 0.24 W m−1 K−1) (PET) (thermal conductivity)

A = heat transfer area

ΔT = temperature difference across medium

L = material thickness



Notes and Observations: