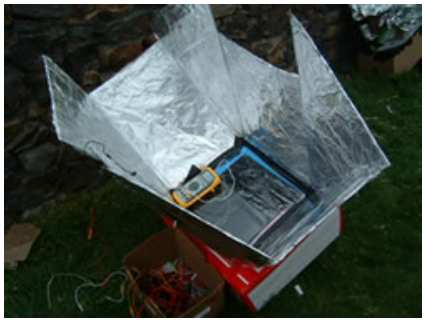
Hands-on Activity: Cooking with the Sun - Creating a Solar Oven

Contributed by: Techtronics Program, Pratt School of Engineering, Duke University

Summary

For this activity, students will be given a set of materials: cardboard, a set of insulating materials (i.e. foam, newspaper, etc.), aluminum foil, and plexiglass. Students will then become engineers in building a solar oven from the given materials, keeping in mind that the oven should not only be able to collect as much of the sun's energy as possible but also to store it. Students will experiment with heat transfer through conduction by how well the oven is insulated and radiation by how well it absorbs solar radiation. Upon completion they will test the effectiveness of their designs both qualitatively and quantitatively. Qualitatively, they will attempt to actually bake something in the ovens. Quantitatively, they will take periodic temperature measurements and plot a temperature versus time graph. Afterwards, students will think like engineers and discuss the solar oven's strengths and weaknesses when compared to a conventional oven.



This is an example of a solar oven built by middle school students at Rogers Herr Middle School in Durham, NC, while participating in Duke University's Techtronics Program.
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Engineering Connection

Category 3. Engineering design

The design, construction, and testing of a solar oven is an engineering project combining materials science with mechanical engineering through harnessing heat transfer mechanisms.

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Grade Level: 6 (6-8)
Time Required: 3.5 hours
Group Size: 3
Activity Dependency:None

Expendable Cost Per Group: US$ 5
Keywords: solar oven, insulation, heat transfer, greenhouse effect
Reviews: Read Reviews | Review/Comment

Related Curriculum:

subject areas	Physical Science Science and Technology
curricular units	Exploring Solar Power
lessons	Using Heat from the Sun

Educational Standards :

North Carolina Science

Does this curriculum meet my state's standards? Select State or (Inter)national) Submit

Pre-Req Knowledge (Return to Contents)

Before doing this activty, students should...

- Have completed the Using Heat from the Sun lesson if the teacher wishes the students to have a fundamental understanding of how a solar oven works.

Learning Objectives (Return to Contents)

At the end of this lesson students should be able to:

- Explain the concept of radiation and give examples of ways that the sun's energy can be collected and stored for useful purposes.
- Explain that certain materials do not conduct heat well and are therefore good for insulation.
- Give examples of different materials that can be used for collecting and storing heat energy from the sun.
- Plot and analyze temperature vs. time data.

Materials List (Return to Contents)

Materials per group:

- 1 piece of Plexiglass (1/4-3/8 inch thickness) that will need to be cut to fit specific dimensions of each oven. A plastic oven bag may also be used for this top layer and is easier to work with. It does not provide as much insulation against heat loss by conduction through the clear layer.
- Scotch tape
- Black duct tape
- 1 Graniteware Pan or regular black metallic cooking pan sized to fit each specific box. Teachers can simply standardize the box size for the entire class to avoid having to buy multiple size pans.
- Foam insulation, which can be acquired at any home improvement store. Each group should be supplied with enough foam to insulate their box. Foam peanuts or newspaper are a less expensive alternative.
- Cardboard boxes of various sizes (at least 2)
- 3-4 feet of aluminum foil
- 1 pair of scissors (must be strong enough to cut corrugated cardbaord if utility knives are not used)
- Glue (optional)
- 3-4 pieces of black construction paper
- Rulers
- 1 utility knife (optional)
- 1 item to be cooked on metallic pan with box (e.g. Break and Bake Cookies (Pre-made cookie dough), Bagel Bites, etc…). Item should be pre-cooked and only require warming.
- 1 thermometer

Introduction/Motivation (Return to Contents)

To motivate students, the teacher might...

- Examine pictures of solar cookers used around the world. Additionally, inform students about statistics illustrating the actual use of solar ovens and solar energy throughout the world, specifically in developing nations. Examples are available at http://www.solarcooking.org.
- Discuss how heat transfer concepts are used to make the oven work. The oven needs to concentrate solar radiation on the center of the oven. The pot or pan must absorb as much solar radiation as possible. Then, the rest of the oven must be designed to resist heat transfer through conduction by insulating the oven.
- How does the oven heat up and stay hot? How does it retain heat? What materials are used?

Vocabulary/Definitions (Return to Contents)

Conduction:	Heat flow due to the contact of two objects or within a solid object.
Convection:	Heat flow due to fluid movement such as water.
Radiation:	Energy transferred through the movement of electromagnetic waves; heat transfer not requiring a medium
Thermal Conductivity:	The property of a material that determines how well it conducts/transmits heat (Examples: metal generally has a high thermal conductivity, plastic generally has a low thermal conductivity)
Insulator/insulation:	A material that does not conduct heat very well and has a low thermal conductivity (Examples: a good jacket, fiberglass insulation, a sleeping bag, anything with air trapped in it)
Emissivity:	Property of the surface of an object that determines how much electromagnetic energy is reflected and how much is absorbed by an object in the form of heat. Emissivity is very dependent on color. (Examples: Aluminum foil has a low emissivity because it reflects a majority of heat and a black surface has a high emissivity because it absorbs a lot of heat; a black shirt gets hotter than a white one in the sun)
Insolation/Solar Radiation:	The amount of power received on the Earth's Surface per unit area (Watts per square meter in the SI unit system)

Renewable Resource:	A resource that is inexhaustible or replaceable by new growth; limitless supply (Example: Solar energy)
Nonrenewable Resource:	A resource that is not replaceable after it has been used (Examples: Fossil Fuels such as oil or natural gas, Iron Ore)

Procedure (Return to Contents)

Using the materials listed above, students should be given the freedom to choose their own designs. The following considerations should be clearly explained prior to building the solar oven.

Design Considerations

- Design should ideally be independent of position of sun. For this purpose, students should be instructed to make use of reflectors and consider designs that would not require them to constantly reposition their solar ovens.
- Heat Loss, Heat Gain, and Heat Storage - Best insulation is a natural substance such as newspaper or Styrofoam. Another option is to use an inner cardboard box and leave a small empty space between the two boxes. It is also important to consider the color of the inside box. Lining the sides with reflective material such as aluminum foil will reflect solar radiation towards the food to be cooked. If the inside is painted, it is important that the paint be non-toxic. (Note: Materials that are likely to melt at 200 to 250 degrees Farenheit should not be used inside the oven. For example, a black garbage bag used to line the inside of the box will melt at high temperatures.)
- The solar oven collects heat through the heat transfer mechanism of radiation. As much sunlight as possible should be reflected towards the food that is being cooked. The pot or cooking container should be a dark color so that it absorbs as much of this solar radiation as possible. Make sure that the box is large enough to hold a dark, lightweight, shallow metallic cooking container. Graniteware, which can be found in any chef store, is a good material to use.
- The solar oven combats heat transfer through conduction through the use of insulation to maintain its temperature. Heat is lost through conduction through the sides of the oven. Insulation slows this heat loss mechanism.
- Convection is generally only a significant heat loss mechanism for a solar oven if it is in a particularly windy environment. Heat loss through convection can be reduced by shielding the solar oven from the wind.

A detailed explanation of how to construct an example solar oven can be found at http://www.backwoodshome.com/articles/radabaugh30.html

- Upon completion, students will test the effectiveness of their ovens on a sunny day by attaching and using a thermometer to measure the temperature every 10 minutes for 1 hour, then every 1 hour for the duration of the school day (at least 3-4 hours total). Alternatively, the teacher could take readings on the ovens during the school day if students are in other classes. They will also bake their cookies in the ovens to qualitatively determine how effective the ovens are.
- Students will use their data to plot temperature vs. time on a graph.
- Students will eat their baked goods.

Safety Issues (Return to Contents)

- Students should be observed closely while cutting cardboard boxes with scissors or utility knives.
- Students should not be permitted to cut the Plexiglas. This should be done by the teacher or by the home improvement store when the material is purchased.
- Utility knives should be used with care. They should only be used under close supervision and are not required for this project.
- Oven mitts should be used to remove cookies.
- Students should be careful when opening their ovens after they have been sitting in the sun. They will be hot and may release steam (which can burn skin).

Troubleshooting Tips (Return to Contents)

- If the ovens are not reaching the desired temperatures, make sure that all seals are tightly closed and air is not leaking out. Make sure any cracks in the box are glued or taped and well insulated and make sure the lid forms a tight seal with the box and where the glass meets the box. Foam around the rim where the lid meets the box can help improve this seal.
- If all seals have been insulated and the box is still not reaching 185 degrees Fahrenheit, make sure that the box is facing toward the sun for at least 20 minutes every hour. This project should only be done during the spring or summer months. If the box still will not heat properly, add more insulation by placing the box inside an even larger container and adding insulation. Finally, perhaps the box is simply too large. Consider making the area that needs to be heated smaller by placing another box within the original space or allow more time for heating.
- Construct the solar oven as desired and then fit the Plexiglass to the box.
- To make the reflectors, simply cover the flaps of the box with tin foil.
- Get plenty of black duct tape, as it tends to run out.
- Foam insulation tends to work better than newspaper.
- The reflectors are hard to attach and sometimes cause the ovens to tip over. Encourage students to stabilize their ovens in case of mild wind.

Investigating Questions (Return to Contents)

- Why is it important to understand heat transfer and storage?
- What advantages does solar energy provide over other types of energy?
- The Sun's corona has a temperature of millions of degrees. Why does it not incinerate us?
- Why and for whom could solar ovens be important?

Assessment (Return to Contents)

General Methods of Assessment

- Class discussion to assess the students' ability to accurately discuss the covered material. Ensure that the students can adequately describe the three basic forms of heat transfer (conduction, convection, and radiation).
- The provided crossword puzzle can serve as a quiz to determine how well the students understand the vocabulary.
- Presentations of solar ovens to the class, in which each student describes how it works and why they made certain material/design choices, such as what type of reflectors and insulation were used.

Teachers can determine whether or not students grasped the key concepts from the solar oven activity by asking the following questions:

- How does the oven work and why did you choose those materials?
- What parts of the solar cooker have high thermal conductivity? Low thermal conductivity?
- How is radiation used?
- Do reflector panels have high or low emissivity? Why?
- How is convective cooling prevented?
- Where are your insulators? What kind of insulation did you choose and why?

Have students compare their temperature versus time plots.

- What oven got the hottest?
- How are the designs different?
- How did differences in design affect performance?

Activity Extensions (Return to Contents)

- Have the students use their oven to cook other food.
- Visit a nearby solar house that uses solar hot water or passive solar heating.
- Determine how well the oven performs in the winter. How important is the season? How important is the time of day? How important is the outside temperature?
- What are the similarities between the greenhouse effect and the solar ovens?

Activity Scaling (Return to Contents)

Scaling of this activity really depends on the amount of interaction between the students and the teacher during the design and building process.

- For advanced students, offer little to no advice and have students research different options so that they may develop their own design. Do not restrict their choice of materials or even offer examples of different devices. Have these students independently test their designs by designing an experiment and ask them to justify their design choices either through a presentation or paper. Students could even modify their designs to determine the importance of individual aspects, such as the color of the box or how different insulators affected the temperature.
- For students who need more help, interact with them through every stage of the planning and building process. Suggest the materials they should use or restrict them so they don't have to make as many choices. Offer a variety of examples or simply instruct all the students to construct their ovens based on an assigned design.

References (Return to Contents)

Making and Using a Solar Cooker

Dabaugh, Joe. "Making and Using a Solar Cooker." Backwoods Home Magazine. Iss. 30, 1998. <http://www.backwoodshome.com/articles/radabaugh30.html>, Accessed 6/2/2004. Making and Using a Solar Cooker - This is an article from Backwoods Home Magazine on building and using a solar oven.

The Solar Cooking Archive

This website has lots of good information on solar cooking and building solar ovens. There are recipes, places solar ovens are used, and plans to build solar ovens.

Solar Cooking International, "The Solar Cooking Archive," <www.solarcooking.org>, 6/2/2004. The Solar Cooking Archive - This is a website with lots of good information on solar cooking and building solar ovens.

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Supporting Program (Return to Contents)

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