Activity 4: Building a Solar Oven

Time Required: 90 minutes
(Testing with food will need to be done on a different day.)

Materials List

Group Size: 3

Each group needs:

- 2 Boxes – about one cubic foot – one which fits inside the other
- Additional cardboard to make panels – could just be one additional box
- Aluminum foil
- An oven bag
- Multimeter with thermocouple

To share with the entire class:

- Black spray paint
- Black construction paper
- Black duct tape
- Insulating materials (rubber foam, Styrofoam, newspaper, etc.)

Youth Worksheets

- Building a Solar Oven Worksheet

Learning Objectives
After this activity, students should be able to:

- Explain that insulation prevents heat loss through conduction.
- Explain that making portions of the inside of the oven black absorbs heat in order to raise the temperature of the oven.
- Explain the flow of energy from the sun to their solar oven and to the object they cook.

Introduction:

During the last few activities, we have measured some values that will help you in designing your solar ovens:

1. You learned that dark colored objects absorb more solar radiation than light colored objects.
2. You explored various types of insulation that can be used to keep heat in your ovens.
3. You learned how to measure the solar azimuth and the solar angle to determine the sun's position in the sky during your class periods. This is important because the sun's rays will be providing heat for your solar ovens.

Now, it's time to begin designing your solar ovens. Let's think back to the first activity involving solar radiation and discuss again the example of getting into a hot car. As we discussed, the car temperature is often warmer than the temperature outside and how warm the car becomes is dependent on the color of the interior. You can use this concept to build a solar oven.

The following describes the behavior of the car and of the solar oven. The interior surfaces are heated by solar radiation. Then through conduction the interior surfaces heat their surrounding. The air will then circulate through the interior of the car or oven and transport heat from the heated surface to the rest of the space. This movement of heat through moving air is called convection. Finally, heat can escape through the walls of the oven or car via conduction. For this reason, there is a maximum temperature the car or oven will reach.

As described in that example, engineers recognize three types of heat transfer:

1) Radiation: Would the car be hotter inside if it had a black interior or a white interior? [Answer: The car would be hotter if it had a black interior. That is because heat transfer via the absorption of solar radiation would be increased.]
2) Conduction: Would the car be hotter if it was made of a single thin sheet of cardboard or 6 inches of foam insulating material used on houses? [Answer: The car would be hotter if it were made of foam insulating material. That is because heat transfer via conduction would be reduced.]
3) Convection: We have not talked about convection much, but it is the third type of heat transfer. Convection is the movement of heat through moving hot air from one place to another. It can also be moving cool air. A fan is designed to increase heat transfer by convection from your body to make you feel cooler. Which would be hotter: a car in the sun on the side of a windy mountain or a car in the sun where there is no wind? [Answer: The car out of the wind would be hotter. That is because there would be less heat transfer away from the car due to convection from the wind blowing. For this reason, it would be better to locate a solar oven where there is less wind.]

You will play the role of an engineer when you are designing and building your solar oven. The design problem is provided to you on your handouts. Your goal is to utilize what you have learned and the materials provided to you to build a solar oven that can attain the highest temperature within half an hour, and can hold a small container that is

Procedure

Before the Activity: 10 Minutes

Boxes and newspaper for this activity are not provided in the kit. Ask the students to collect one box each and some newspaper from home for their solar ovens. In addition, it is a good idea for you to pick up some boxes and newspaper just in case the students forget. You can find boxes in the recycling bins of many stores. Newspaper is often left behind where newspapers are freely distributed. It may also be found in recycling bins.

This activity will generally take 2-3 class sessions. It can be good to encourage students to bring in additional materials from home. This lets students really think about what they want their oven to look like. It also gives them an opportunity to think more about the project outside of class. Be sure they are not bringing in expensive materials they had to buy that might give one group an advantage. As an example, students should not go to a home improvement store to buy insulation. You could either say that materials a group obtains outside of the ones provided must not cost more than $5-10 total, or you could even say that materials obtained must be freely available. This is up to the individual instructor.

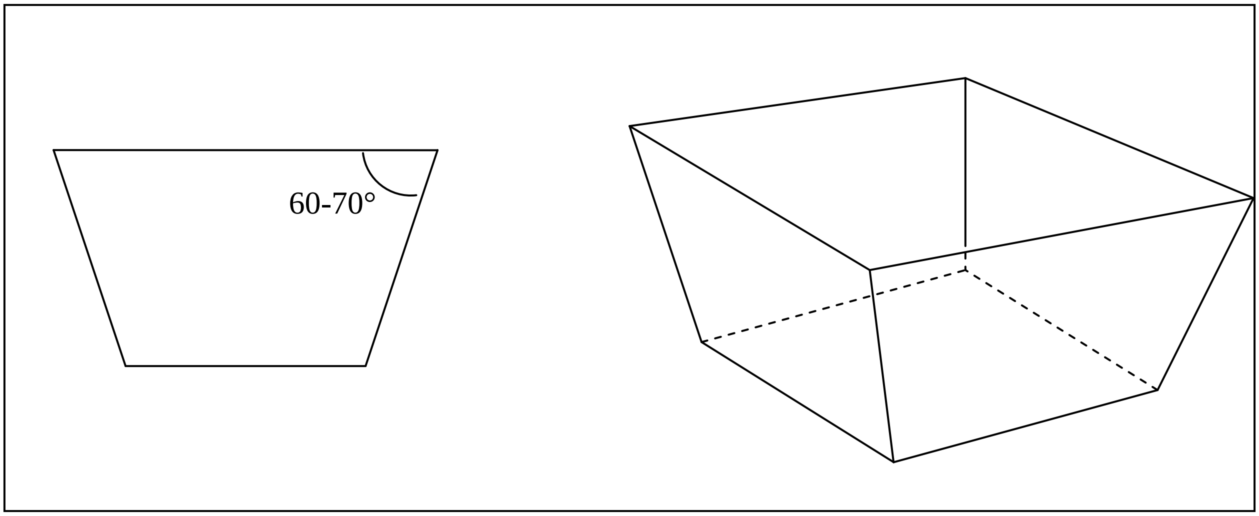
During the Activity:

The solar oven engineering design project is outlined in the student handouts.

The construction of the ovens should be guided by the materials chosen. Students should be encouraged to use different materials where available to experiment with what works better. The two nested boxes provide the external and internal walls of the oven while the oven bag serves as the transparent window. Insulation is placed between the boxes. Newspaper can serve as a very good form of insulation. Portions of the interior box, or wall of the oven, may be painted black to increase heat it will absorb by solar radiation. Black containers for cooking will help with this as well. It is also useful to reflect sunlight directly towards the areas where cooking is occurring.

Students are provided with the opportunity to reflect additional sunlight towards the interior of the oven using aluminum foil as a reflector. These will typically require some kind of backing probably made from cardboard cut from one of the boxes. The students must determine their own reflector configuration and how many panels they would like to use. In this way, they must think about where the sun is coming from and how to orient their boxes.

Some students will use a single reflector to reflect sunlight into the oven. Others might try more complex arrangements. One of the most efficient arrangements, if the students can figure out how to mount the collectors in place, is to put four collectors on top of the oven as shown below. The panels could be trapezoidal with angles in the range of 60-70°. The solar oven may need to be propped in order to point at the sun. The ovens will need to be moved while cooking so that the sun is always directed into the oven.



The most important thing the students can do to create solar ovens that will work well is to make sure there are no places where air can flow out of the interior of the oven. If the hot air can just flow out of an open space in the oven, the insulation will not be able to keep the heat in.

Processing and Activity Closure:

While the goal of the activity is to build and use a solar oven, the objective of the lesson should focus on what makes each oven different. Students should discuss as a class what is different about each oven. It is useful to list the specific parameters of each box; for instance, did one group not paint the inner walls black? Did one group not use aluminum foil or a collector at all? To test the ovens, each group should set up the oven outside on a sunny day and measure the air temperature inside the oven and plot that temperature as time progresses, as they did in Activity 2. Measurements may be taken every 10 minutes for a total of 30-40 minutes after which time the increase in temperature should begin to slow down, assuming the oven is empty.

The class data should be compiled so that students can observe the different heating curves that the other groups obtained and what different variables caused those changes.

Questions during the class data analysis offer more opportunities for the students to make connections and draw conclusions about the construction decisions made in the construction of the ovens. As the students observe all of the solar ovens in action, ask the students some of the following questions to help them think about what they just accomplished:

- Which solar ovens worked really well?
- Why do you think a particular solar oven worked well?
- How can a particular solar oven that did not work as well be improved?

After these ovens have been tested once to determine how hot they will get, it is time to test them with food (they may be tested with food during the next session). As the maximum temperature of the ovens may not be high enough to cook all food, it is recommended that you find something that is thin and is ok for the students to eat even if it does not fully cook. Pre-made cookie dough works well. You can back cookies in the oven on small pieces of aluminum foil. Do not place the cookies directly on spray painted aluminum foil. Place a layer of aluminum foil that has not been spray painted as a barrier for the food.

Embedded Assessment
Collect and copy page 29-30 from each group. The questions on both of these pages will assess student understanding of conduction, radiation, and how solar ovens utilize these two science concepts to heat a solar oven.

Authors (Contributors):

Engineering Design Activity – Building a Solar Oven Student Handout

Name: ___________________________________

Date: _____________________

In this exercise, you will play the role of an engineer while you are designing and building a solar oven. Keep in mind what you have learned about heat transfer and the movement of the sun in the sky in the previous activities.

Materials

Your group will receive:

- 2 Boxes – about one cubic foot – one which fits inside the other
- Additional cardboard to make panels – could just be one additional box
- Aluminum foil
- An oven bag
- Multimeter with thermocouple

The following materials are available to share with the class:

- Black spray paint
- Black construction paper
- Black duct tape
- Insulating materials (rubber foam, Styrofoam, newspaper, etc.)

Engineering Design Problem:
The design problem is to utilize what you have learned and the materials provided to build a solar oven that can attain as high a temperature as possible.

Engineering Design Specifications and Constraints:

- The interior of the oven must be large enough to hold whatever container you plan on using for cooking. In this case, you will want to be able to cook at least a few cookies on a piece of aluminum foil, or heat up water in a small teacup to make tea. To meet these requirements, the base of the interior of your oven must be at least 6"x6" and the height of it must be at least 4". Depending on the boxes you have, you are welcome to make your oven much bigger than this.
- You must be able to open and close your oven somehow. An oven bag is provided to create a transparent window. You must find a means of attaching this to your oven in order to create a lid. This way, food may be put in the oven or removed from the oven.
- Another reason you must be able to open and close your oven is to mount the thermocouple wire inside the oven. Once your oven is finished, mount the end of the thermocouple wire inside your oven with tape approximately one inch above the bottom and so that the tip is approximately one inch from the wall.

Design Tips

Insulation: Reducing heat loss through conduction

Utilizing two boxes, an inner and an outer box will provide a place for insulation to reduce heat transfer out of the oven. In between the inner and outer wall, you can place insulating materials the oven. Your instructor will have some materials available for you to choose from to insulate your oven. In general, the amount of insulation – how tight you pack it into that region – will change how well your oven retains heat. Use the results of your experiments from Activity 3 as a guide. You may not be able to use large amounts of the best insulation so think about how best to utilize it.

Interior Color: Increasing heat gain from solar radiation

When constructing your oven, you should try to maximize the amount of radiative energy, or sunlight, into the oven. Recalling the analogy of the car, the color of the interior of your car does affect the amount of energy transferred from radiative energy (sunlight) to heat. You may wish to experiment with painting portions of the interior black. Black containers for cooking will absorb more heat than other colored containers. It is also useful to reflect sunlight directly towards the areas where cooking is occurring.

Reflectors: Increasing the amount of solar radiation entering the oven

The maximum amount of solar radiation that your oven can currently collect is the amount that strikes the opening of your oven. One way to gather more radiative energy is to use reflectors to catch more light. You can use up to four cardboard reflectors. You must determine where you think the reflectors will be most useful in collecting the suns rays.

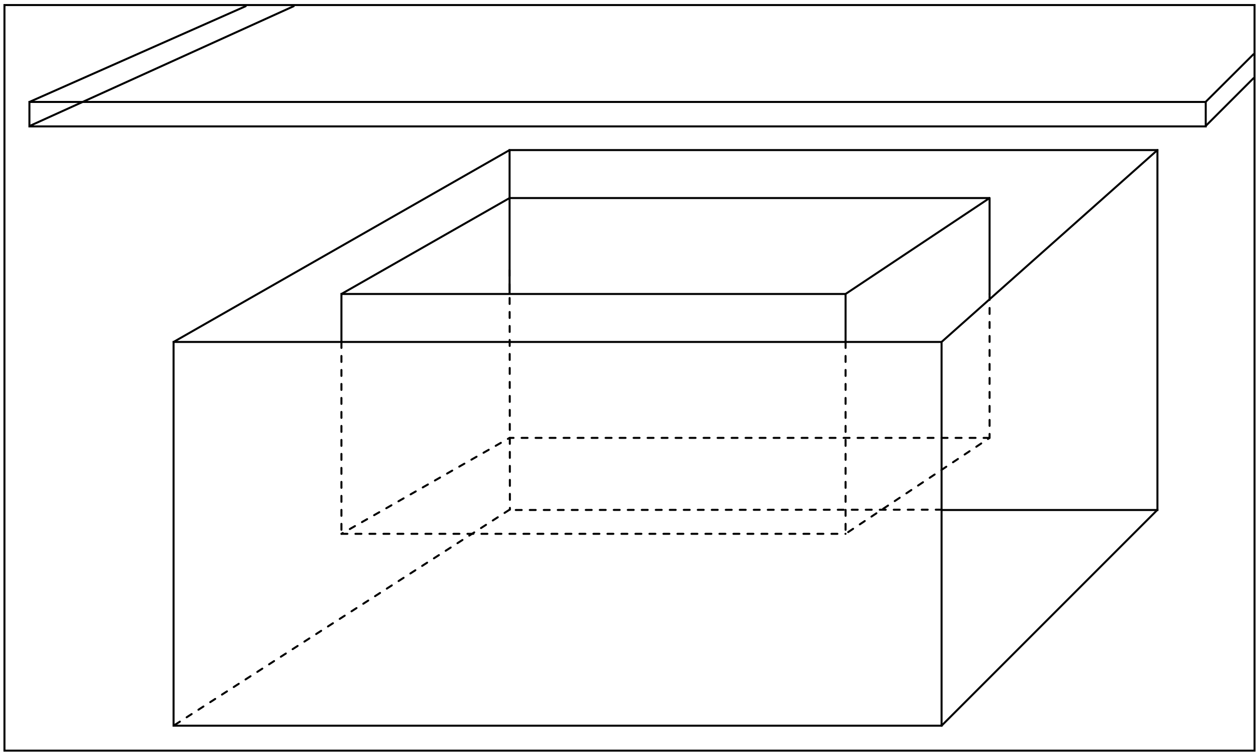
Oven Lid

The last component of your oven is the lid. The lid will be placed on top of your oven, underneath your collector. Remembering the car that heats up, think about what happens when you open the door – hot air comes flowing out. As opposed to your car, we actually want all of the hot air to stay in, so do your best to seal the oven when the lid is in the closed position. Remember, there must be a method to open and close the oven to put food in and take it out.

Blocks can be used to prop the oven up so that it is pointing at the sun. The ovens will need to be moved while cooking so that the sun is always directed into the oven.

Analysis:

To test the ovens, set up the oven outside on a sunny day and measure the air temperature inside the oven. Measure the temperature every 10 minutes and graph your results. After the first 30 minutes, you can take measurements less often. The class data should be compiled so that all students can observe the different heating curves that the other groups obtained and what different variables caused those changes.



This drawing shows the box within a box of the solar oven without reflectors.

Questions:

Was it cloudy, partly cloudy, or sunny when you tested your solar oven?	
What was the outside temperature during your test?	
What time of day did you perform your test?	
What temperature did your solar oven reach 30 minutes after it had been sitting in the sun?	

Draw a diagram of your solar oven below. Please label where there is heat transfer due to radiation, and label where there is heat transfer due to conduction.

Explain how a solar oven works.

What aspects of your solar oven design worked well?

How could your solar oven be improved?