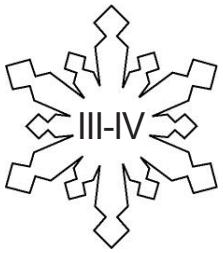
Solar Box Cooker

Levels



Grades 5-8

Overview:

Heat is transferred in three ways: convection, conduction, and radiation. In this lesson, students explore heat transfer by creating a simple solar box cooker, and then use their knowledge of energy transfer to improve their design. Students relate their learning to permafrost and climate change.

NOTE: This lesson requires more than one class period. Testing the solar cooker works best on a sunny day, however students may design and build their box cookers on overcast or rainy days, and then test them on a sunny day.

Objectives:

The student will:

- create a concept map that demonstrates the relationship between energy transfer and permafrost and/or climate change;
- design and build a solar box cooker;
- draw a diagram of heat transfer in a solar box cooker; and
- write instructions for building a solar box cooker and share his or her method with the class.

GLEs Addressed:

Science

[5-8] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating.

[6] SD3.2 The student demonstrates an understanding of cycles influenced by energy from the sun and by Earth's position and motion in our solar system by identifying that energy transfer is affected by surface conditions (e.g., snow cover, asphalt, vegetation) and that this affects weather.

[8] SD3.2 The student demonstrates an understanding of cycles influenced by energy from the sun and by Earth's position and motion in our solar system by recognizing types of energy transfer (convection, conduction, and radiation) and how they affect weather.

[6] SE2.1 The student demonstrates an understanding that solving problems involves different ways of thinking by identifying and designing a solution to a problem.

[7-8] SE2.1 The student demonstrates an understanding that solving problems involves different ways of thinking, perspectives, and curiosity by identifying, designing, testing, and revising solutions to a local problem.

[6-8] SE2.2 The student demonstrates an understanding that solving problems involves different ways of thinking by comparing the student's work to the work of peers in order to identify multiple paths that can be used to investigate a question or problem.

Writing

[5-6] W2.2.2 The student writes for a variety of purposes and audiences by writing in a variety of nonfiction forms using appropriate information and structure (i.e., step-by-step directions, descriptions, observations, or report writing).

Materials:

- Pizza box (two per group)
- Black construction paper
- Aluminum foil
- Heavy clear plastic, such as visqueen

- Glue
- Tape
- Scissors (one pair per group)
- Ruler
- Wooden dowel or stick (one per group)
- RUBRIC: “Solar Box Cooker”
- STUDENT INFORMATION SHEET: “Principles of Solar Cooker Design”
- STUDENT INFORMATION SHEET: “Make a Solar Box Cooker”

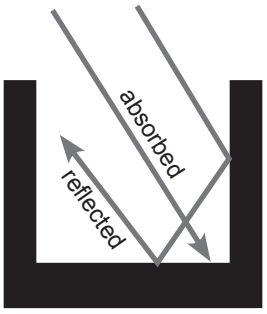
NOTE: Students may wish to use other materials in the modification of their design.

Whole Picture:

Solar box cookers are designed to heat things, mainly to cook food or sterilize water. Solar box cookers cook through heating of the interior of the box using the energy of the sun (solar radiation). Sunlight (solar radiation) enters the box and is absorbed and reflected by the surfaces inside the box.

The albedo of a surface tells how much solar radiation is reflected off of the surface. Dark surfaces have a low albedo; they do not reflect very much solar radiation, meaning they absorb a large amount of solar radiation. Light colored surfaces reflect a large amount of solar radiation.

On the surface of the ground, solar radiation is reflected back into the atmosphere. In a confined space, such as a solar box cooker, solar radiation can be reflected against other surfaces, as shown below. This type of heat transfer is called radiation.



Solar radiation reflected and absorbed

Heat is mainly transferred through conduction and convection. If the bottom of a solar box cooker is a dark material (such as black construction paper) that absorbs solar radiation, it will transfer that absorbed heat to anything that is touching it through the process of conduction (direct transfer of heat from one object to another).

The air inside the box is heated through conduction and convection. As air at the bottom of the box is heated, it rises and is replaced by cooler air from the top of the box. This air in turn is heated and replaced in a continual circular motion.

For example, if a pot of water is in the solar box cooker, the pot itself will be heated through direct solar radiation, radiation that is reflected off the sides of the cooker, and through heat that is conducted from where the pot touches the cooker. The water is heated through conduction and convection. The heat from the sides of the pot transfers to and heats the water; convection causes the water to circulate and contributes to the heat gain. Maximizing the effectiveness of a solar cooker involves balancing heat loss and heat gain.

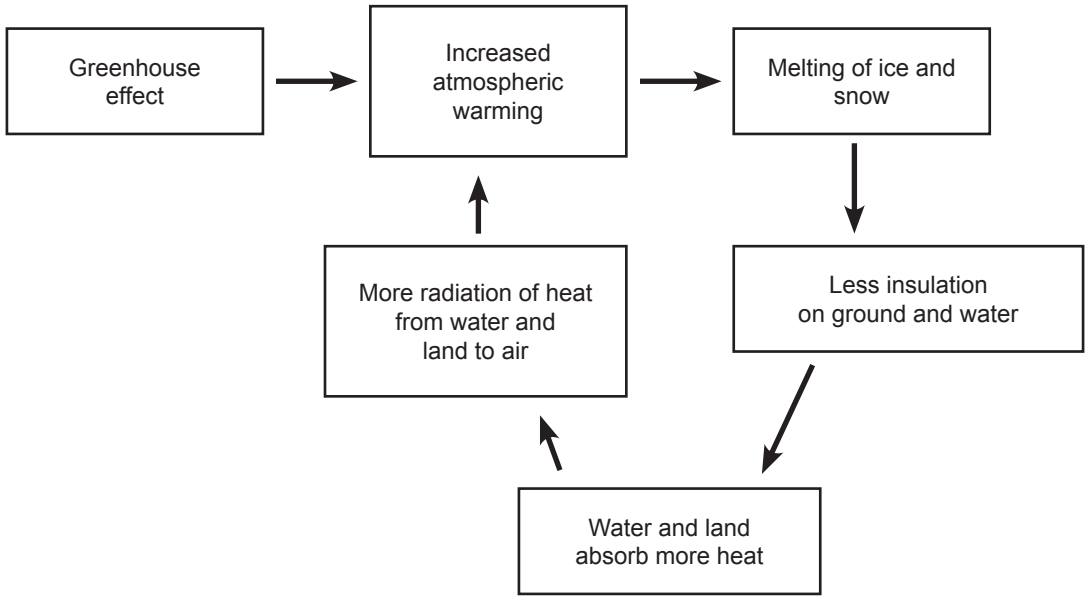
The STUDENT INFORMATION SHEET: “Principles of Solar Cooker Design” explains some of the factors involved in maximizing the effectiveness of a solar box cooker.

Activity Procedure:

Building a Simple Solar Cooker

1. Explain in this activity students will build a basic solar box cooker, and then use their knowledge of heat transfer to improve their basic solar cooker design. Share the rubric with students.
2. Divide students into groups. Distribute the STUDENT INFORMATION SHEET: “Make a Solar Box Cooker” to each student and a set of supplies (as specified on the student information sheet) to each group.
3. Guide students through the creation of their box cooker.
4. Distribute a thermometer and timer to each group. Ask groups to place their thermometer in their box, wait 30 seconds, and record the initial temperature of their solar cooker. Ask students to record the temperature again after 5 minutes. Collect group results and list on the board.
5. As a class, discuss why results may vary. (Angle of box on the ground, tighter or looser seal on lid, angle of lid, etc.)
6. Distribute the STUDENT INFORMATION SHEET: “Principles of Solar Cooker Design,” and ask students to read the worksheet individually or in their groups.

Critical Thinking Question: Concept Mapping Method. A concept map illustrates connections between terms or concepts. Concept maps help students to determine relationships and organize information. Have students construct concept maps by writing words then drawing lines to connect terms or concepts that share a relationship. Ask students to develop a concept map that links together the concepts presented in the STUDENT INFORMATION SHEET: “Principles of Solar Cooker Design” and climate change and/or permafrost. Student concept maps may look like this:



If necessary, explain how snow cover affects permafrost. Snow cover insulates the ground, making it difficult for heat to escape the soil. As snow cover increases, more heat is trapped below the surface of the soil, contributing to permafrost thaw.

Improving the Design

7. Ask groups to use the STUDENT INFORMATION SHEET: “Principles of Solar Cooker Design” to draw a plan to improve the basic solar cooker design they already constructed. Instruct groups to document each design change.
8. Ask groups to create a list of supplies and write directions for assembly of their improved solar cooker. Explain students are limited to the supplies given out earlier, but they can use any quantity or arrangement of items. Approve designs and distribute materials.
9. Provide each group ample time to construct their solar box cooker. When all groups are done with construction, test the cookers by repeating the thermometer measurement in Activity Procedure 4.
10. Share results as a class. Instruct each group to prepare a presentation of their solar box cooker. Groups should explain the cooker’s construction, the design choices they made, the reasons for each choice, and the performance of their cooker. Encourage groups to explain how they might further change their cooker to increase performance.

Extension Ideas:

Make s’mores, English muffin pizzas, heat hot dogs, or bake cookies or potatoes in the solar box cookers.

Students may wish to research the angle of sunlight for a particular day at their location and use a protractor to adjust the tilt of their box lid accordingly to take maximum advantage of the solar radiation. ([7] MEA-5)

Make a Solar Box Cooker

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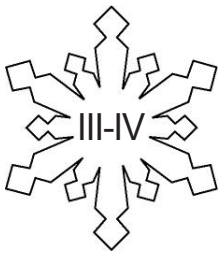
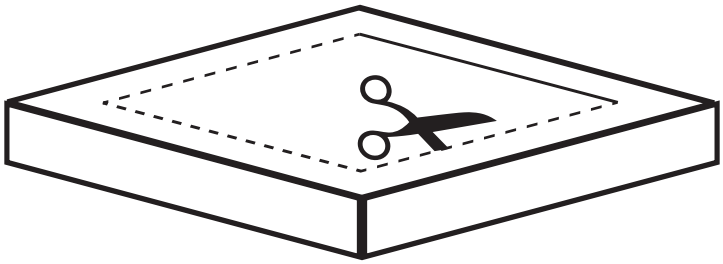


Materials

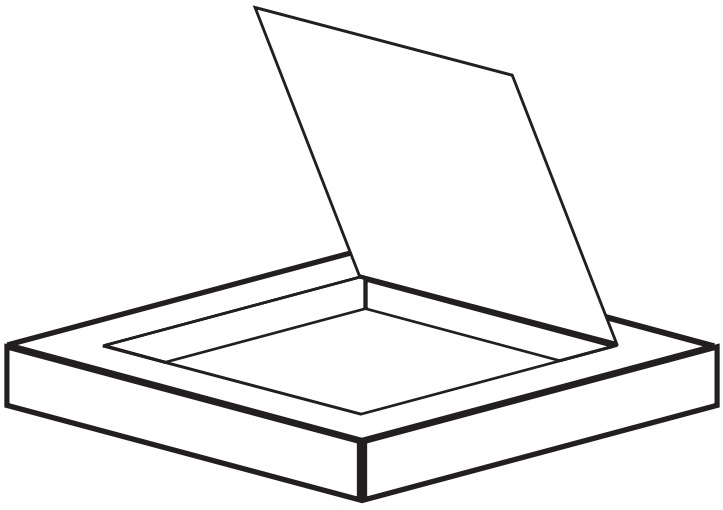
- Pizza box
- Black construction paper
- Aluminum foil
- Heavy clear plastic
- Glue
- Tape
- Scissors
- Ruler
- Wooden dowel or stick

Procedure

STEP 1. Draw a one-inch border on all four sides of the top of the pizza box. Cut along the sides, leaving the line along the back of the box uncut.



STEP 2. Form a flap by gently folding back along the uncut line to form a crease.



Make a Solar Box Cooker

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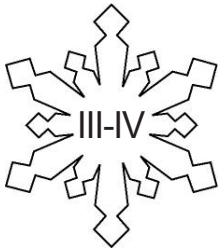
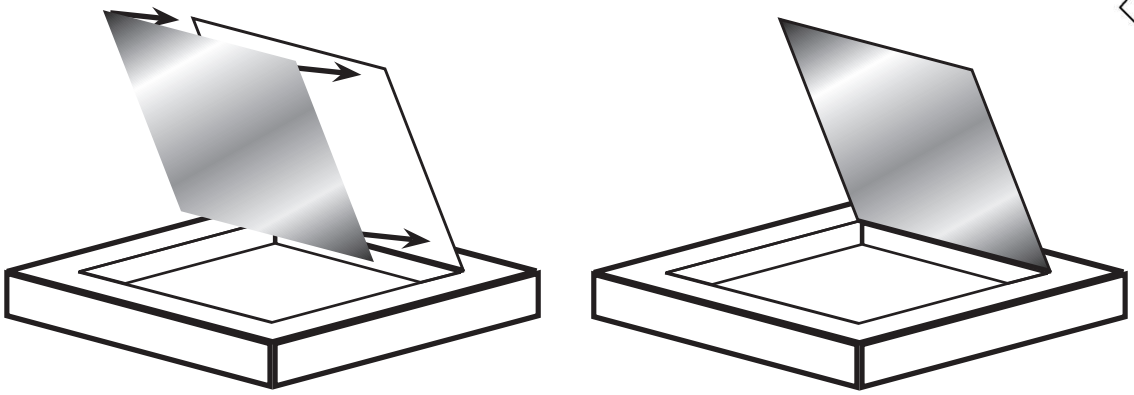
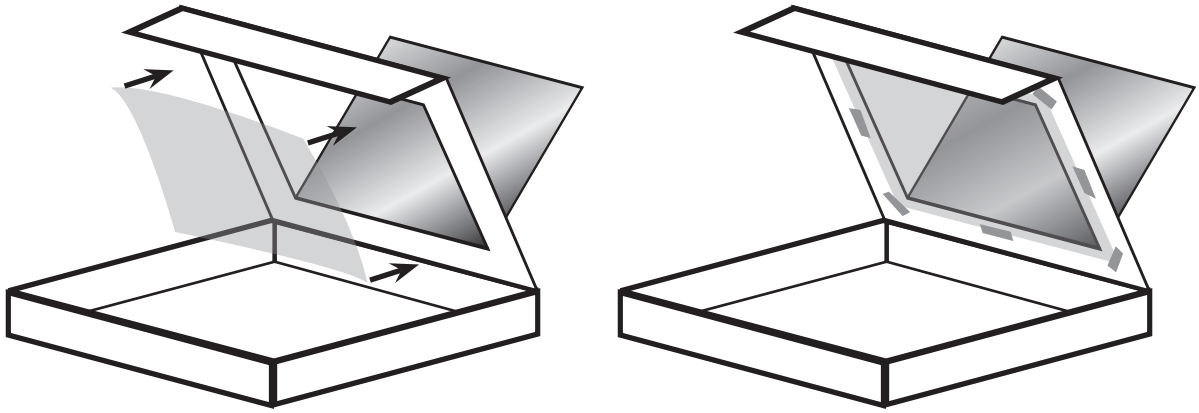


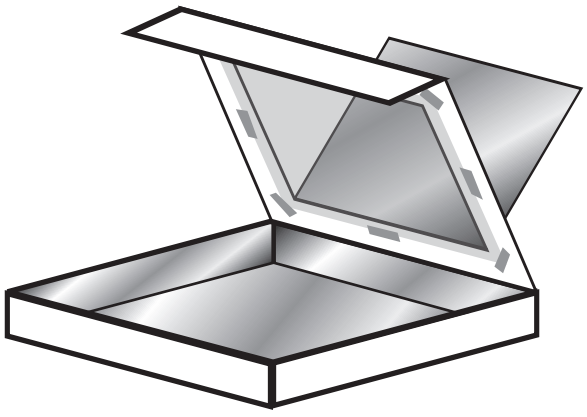
STEP 3. Cut a piece of foil to fit on the inside of the flap. Smooth out any wrinkles and glue into place.



STEP 4. Measure a piece of plastic to fit over the opening you created by forming the flap in your box. The plastic should be larger than the opening, so it can be taped to the underside of the top of the box. Tape the plastic to the underside of the lid of the box. Be sure to seal all sides of the plastic with the tape.



STEP 5. Line the bottom and sides of the inside of the pizza box with foil and carefully glue into place.



Make a Solar Box Cooker

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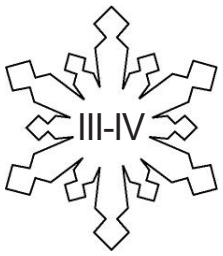
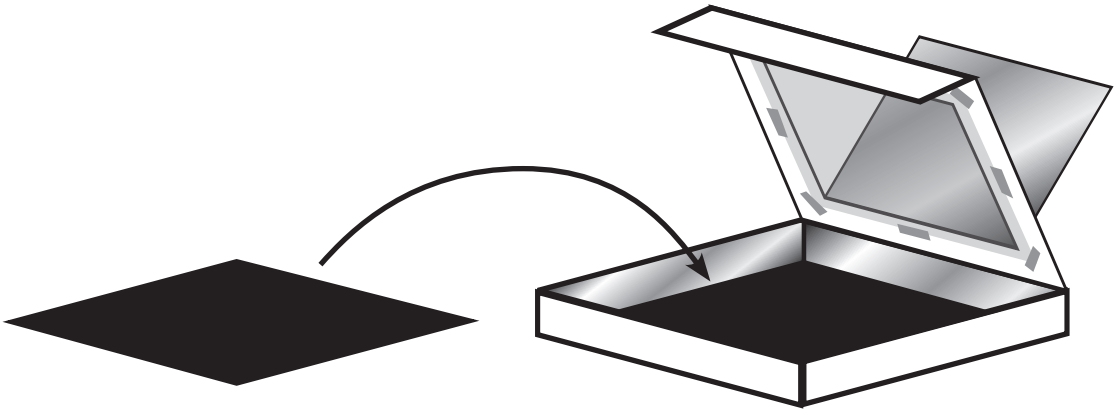
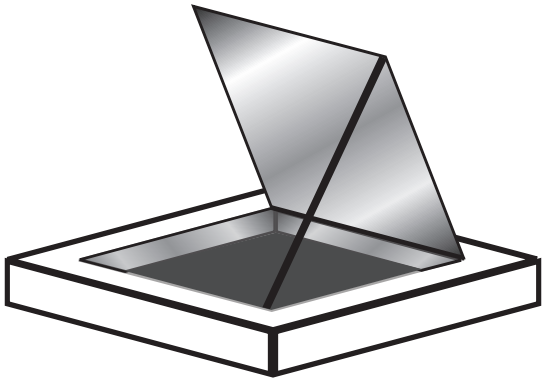


STEP 6. Cut a piece of black construction paper to fit the bottom of the box and glue into place.



STEP 7. Close the pizza box lid, and prop open the flap with a wooden dowel or stick. Face the flap toward the sun.



Principles of Solar Cooker Design

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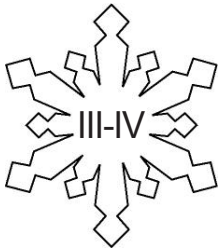
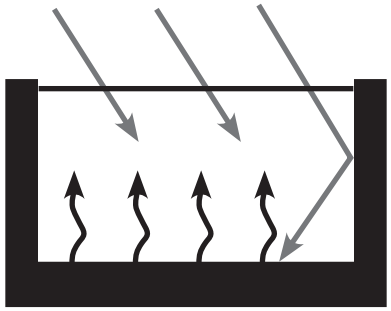


Greenhouse Effect

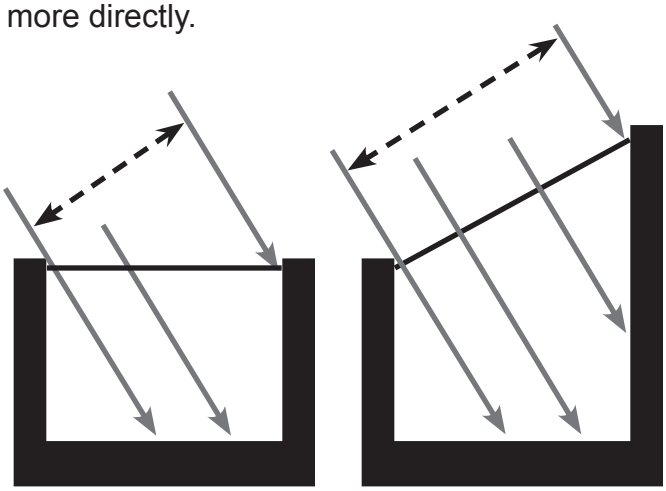
A solar cooker can work without a transparent lid; however, a transparent lid, such as clear plastic or glass, will enhance performance by taking advantage of the greenhouse effect. As visible light (short wavelength) passes through the plastic or glass, it is absorbed and reflected by the materials within the box. Energy absorbed by the cooker is later radiated back into the box. Most of this energy now has a longer wavelength, which prevents it from escaping the glass. Without the lid, much of the energy absorbed by the cooker itself will be radiated back out of the box.



Greenhouse effect

Glass Orientation

If glass or plastic is used, the more directly the glass faces the sun, the greater the solar heat gain. Although the glass is the same size on box 1 and box 2, more sun shines into box 2, because it faces the sun more directly.



Box 1 Box 2

Principles of Solar Cooker Design

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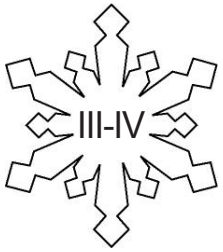
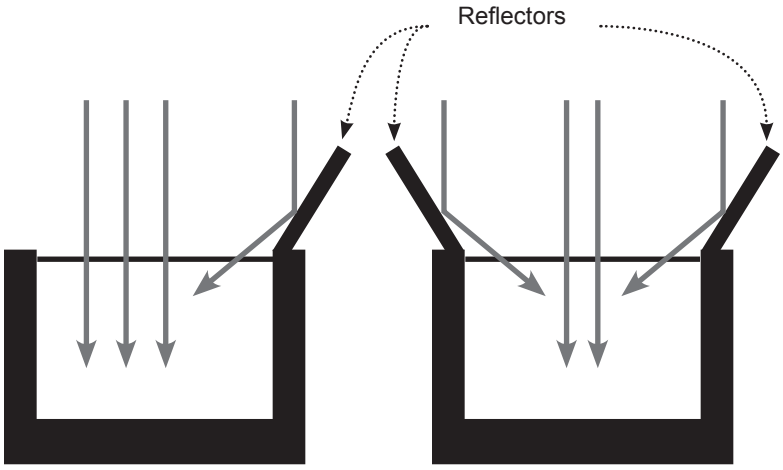


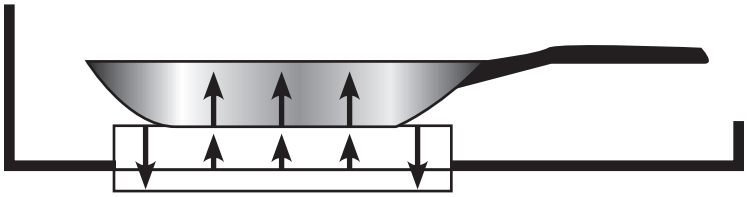
Reflectors

Reflectors bounce additional sunlight through the glass or plastic and into the solar cooker box. This additional input of solar energy results in higher cooking temperatures. Single or multiple reflectors can be added to maximize solar input.



Conduction

Conduction is the transfer of heat from one object directly to another. In a solar cooker, heat is conducted from the bottom plate to the bottom of the pot (or thermometer). This is important for cooking food. However, heat can also be lost via conduction through the bottom of the cooker. To reduce this, a plate with spacers can be added to the bottom of the box.



Conduction

Radiation

While most of the radiation in a solar cooker comes from the sun, the interior of the box, pots, and bottom plates, also radiate heat. Most of the radiant heat given off by the warm pots within a solar box is reflected back into the box by the glass and foil; however, some of it is lost through the glass or plastic covering. Altering the covering can reduce this heat loss. For example, glass works better than most plastics.

Principles of Solar Cooker Design

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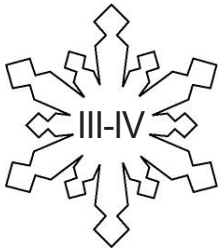
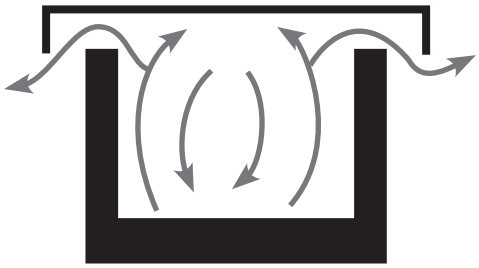


Convection

Convection is the movement of heat in a circular motion, typically through air or water. In a solar box, heated air molecules rise. Cracks in the box can result in heated air escaping from the box.



Convection

Insulation and Heat Storage

Objects have a certain heat capacity, the amount of heat they can hold. Certain objects can hold large amounts of heat and radiate it slowly. These objects, such as bricks, heavy pans, and water, increase the effectiveness of the cooker (although they may take longer to heat up). Adding these materials to the sides or bottom of a solar cooker can increase the heat storage of the box. Similarly, insulation around the outside of the box can help hold heat longer.

SOLAR BOX COOKER

RUBRIC

Objective	GLE	Below Proficient	Proficient	Above Proficient
The student creates a concept map that demonstrates the relationship between energy transfer and permafrost and/or climate change.	[6] SD3.2 [8] SD3.2	The student does not create a concept map, or incorrectly demonstrates the relationship between energy transfer and permafrost and/or climate change.	The student creates a concept map that accurately demonstrates the relationship between energy transfer and permafrost and/or climate change.	The student creates a concept map that accurately demonstrates the relationship between energy transfer and permafrost and/or climate change. The concept map includes the albedo effect (atmospheric warming leads to ice melting, which leads to decreased albedo, or ability to reflect, which leads to further ice melting, and so on).
The student designs and builds a solar box cooker.	[6] SE2.1 [7-8] SE2.1	The student does not design and/or build a solar box cooker, or his or her design does not work properly (i.e. does not increase the temperature within the cooker).	The student designs and builds a solar box cooker that works properly, and records each design modification and the scientific reason for the decision.	The student designs and builds a solar box cooker that works properly, and records each design modification and the scientific reason for the decision. The student correctly explains how each design choice improves the performance (heat transfer) of the cooker.
The student draws a diagram of heat transfer in a solar box cooker.	[5-8] SA1.1 [6] SD3.2 [8] SD3.2	The student does not draw a diagram of his or her solar box cooker, or incorrectly labels the path of heat transfer to and within the cooker.	The student draws a diagram of his or her solar box cooker, correctly indicating the path of heat transfer to and within the cooker.	The student draws a diagram of his or her solar box cooker, correctly indicating the path of heat transfer to and within the cooker. The student also labels each type of heat transfer correctly (radiation, convection, conduction).
The student writes instructions for building a solar box cooker and shares his or her method with the class.	[5-6] W2.2.2	The student does not write step-by-step instructions for building a solar box cooker, or the student's instructions are unclear and difficult to follow.	The student writes step-by-step instructions for building a solar box cooker and explains his or her instructions to the class. The student's instructions are clear and easy to follow.	The student writes step-by-step instructions for building a solar box cooker and explains his or her instructions to the class. The student's instructions are clear and easy to follow. Diagrams are included where necessary.