

What's Cooking 2

Student Objective

The student:

- will calculate the calorie heat gain for several different containers
- given containers of several different materials can determine which will work the best in a solar cooker.

Materials

- box or panel cooker from previous What's Cooking investigation
- containers made of various substances such as: foam cup, clear plastic glass, colored glass, metal can, ceramic mug, glass beaker, ½ pint milk carton, milk carton painted black (4 assorted per group)
- graduated cylinder
- thermometers (5 per group)
- plastic wrap
- pot holders

Key Words:

conduction
convection
dependent variable
independent variable
radiation
solar collector
solar thermal
specific heat
thermal conductivity

Time:

1 class period

Background Information

The transfer of heat is accomplished by convection, conduction and/or radiation. Heat energy flows in the direction from higher temperatures to lower temperatures, with the rate of flow being directly proportional to the temperature difference. **Convection** requires the movement of a fluid (or mass) from one position to another. The movement of air or water is an example of heat transfer by convection. The transfer of heat energy by air and water currents is essential in distributing heat energy over the Earth's surface.

Conduction is the transfer of heat energy by molecular activity. The kinetic energy of the molecules is transferred from one molecule to another through collisions. The thermal conductivity of a substance is a measure of its ability to conduct heat with the better conductors having a higher thermal conductivity value. Substances with high thermal conductivity values are silver, copper, and aluminum. Substances such as soil, glass, water and air have low thermal conductivity values.

Radiation is the process of transferring heat energy through space by means of electromagnetic waves. These waves carry energy and can travel through a vacuum, such as the energy of the Sun traveling through the vacuum of space to our Earth. Heat energy in the form of

electromagnetic waves is both absorbed and reflected when it hits a surface.

Procedure

1. Place the box of various containers in the front of the room.
2. Divide students into groups of 4 - 5 students in each group.
3. Explain procedure to the class:
 - Each group will be testing four containers for their ability to gain heat in their solar cooker.
 - Pour 100 mL water into each container.
 - Put a thermometer in the water of each container.
 - Prepare the container for the type of cooker being used. Cover the top around the thermometer with plastic wrap and secure with rubber bands for box cookers and for panel cookers place the container and thermometer in an oven bag. Panel cookers will also have one thermometer placed inside the oven bag to measure the air temperature.
 - Place the cooker in the sun. Put the containers in the cooker so the thermometers will be easy to read. Oven cookers will also have one thermometer placed in the oven but not in a container to measure air temperature.
 - Record the temperature after 30 minutes (or longer if class time allows) and calculate the heat gain.
4. Help students as needed during the experiment.
5. Write the formula for calorie heat gain on the board:
Heat gain/loss = mass (Q Δ T)
Where Q is the specific heat gain of a substance and Δ T is the change in temperature (positive value changes mean the temperature increased; negative values mean the temperature decreased).
6. Students should complete their Laboratory Manuals.
7. The Problems may be assigned for individual work, homework or testing.

Evaluation and Student Assessment

Activity and Teamwork: 50%

- Are the students working cooperatively?
- Are the students following activity directions?
- Are the students solving problems?

Lab Results and Problems: 50%

Answer Key - Laboratory Manual

1. Student answers will vary. Check student math.
2. No. The temperature of the water in a closed container will increase at a slower rate than the air in the oven due to the lower specific heat of air as compared to liquid water. Additionally, water in a closed container will not increase above 100° C due to evaporation and condensation.

3. Answers will vary, but students should have an understanding that materials with a higher mass and/or higher specific heat values will conduct a larger amount of heat to the water.
- 4 - 5. Student answers will vary. Check student math and unit procedures:
 $Q = m C \Delta T$ where:
 - m = mass in kg (m for 100 ml of water = 100 g = 0.1 kg)
 - C = specific heat values from data table ($C = 4180 \text{ J / kg K}$ for water)
 - ΔT will depend on student data results (final temperature - initial temperature)
 Note: changes in temperature on the Kelvin scale will equal the same change in temperature on the Celsius scale.

Answer Key - Problems

1.
 - a) Al = 336,375 J
 - b) Brass = 141,000 J
 - c) Cu = 144, 375 J
 - d) glass = 315,000 J
 - e) Fe = 168,750 J
2. The container requiring the least amount of energy will heat up the fastest - Brass
3. Brass, copper, iron, glass, aluminum
4. $Q = m C \Delta T$
 $C = Q/m \Delta T$
 $5775 \text{ J / 1 kg (15}^\circ\text{C)} = 385 \text{ J/kg } ^\circ\text{C}$ which is copper

Key Words and Definitions

- **conduction** – the movement of heat through materials by transferring kinetic energy directly from particle to particle
- **convection** – the circulatory movement or transfer of heat through fluids such as air or liquids due to differences in temperature (hotter fluids rise and cooler fluids sink)
- **dependent variable** – a condition of the experiment that is found by testing different values of the manipulated condition. The values of the dependent variable are the effects that are seen from manipulating the independent variable.
- **independent variable** – a condition of the experiment whose values are specified first or before an experiment is performed and are used to compare other values or results. Changing the values of the independent variable can be said to cause what happens to the dependent variable.
- **radiation** – the way we receive heat from the Sun each day. The energy is emitted in the form of waves or photons (electromagnetic waves) and can be transferred through the vacuum of space.
- **solar collector** – a device that collects and traps solar energy
- **solar thermal** – using the Sun’s energy to heat something
- **specific heat** – the amount of heat, measured in calories, required to raise the temperature of one gram of a substance by one Celsius degree
- **thermal conductivity** – the measure of a substance’s ability to conduct heat. The higher the value, the more conductive the substance.

Related Research

1. Test additional types of containers.
2. Compare class results with other classes during the day. Does the time of day make a significant difference? When is the best time to use a solar cooker?
3. Check the temperature each hour. Does the rate of heat gain change? Explain.
4. What will happen if the clear containers had a black bottom or a black outside? Investigate.
5. What will happen if the containers were placed on a wire rack? Investigate.
6. Will one large container reach the same temperature as fast as several smaller containers with the same total amount of water? Investigate if surface area is a variable to heat gain.
7. We have all heard the expression “it’s so hot you could fry an egg on the sidewalk”. Actually, this cannot work using just an egg and a regular sidewalk. Research the properties of frying eggs that makes this impossible. What would you have to do to the sidewalk, the Sun’s rays, and/or the egg to make it possible?

Related Reading

- ***Cooking With Sunshine: The Complete Guide to Solar Cuisine with 150 Easy Sun-Cooked Recipes*** by Lorraine Anderson and Rick Palkovic (DaCapo Press, 2006)
This book includes simple, straight-forward recipes suitable for homemade box and panel cookers.
- ***Solar Cooking for Home & Camp: How to Make and Use a Solar Cooker*** by Linda Frederick Yaffe (Stackpole Books, 2007)
This book written by a lifelong camper, includes instructions for building a box and a panel cooker, easy to prepare solar recipes and great tips for solar cooking while camping

Internet Sites

<http://www.fsec.ucf.edu/go/energywhiz>

Florida Solar Energy Center’s annual solar cooking competition, the Solar Energy Cook-off for grades 4 through 12. Includes rules and information on how to enter a team. The page also includes links to cookbooks of the winning student recipes from the competition.

<http://solarcooking.org/>

Solar Cooking International, solar cooking archive includes solar cooking plans, documents and a list of resources and manufacturers.

<https://www.sunoven.com/basics-of-cooking-with-the-sun-a-free-interactive-online-class/>

Sun Ovens International. Basics of Cooking With the Sun, free online solar cooking class. Although this video is presented to showcase the Sun Oven (that they sell), the video includes many helpful hints that are good for any solar cooker.

What's Cooking 2

Florida NGSS Standards & Related Subject Common Core

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Nature of Science																						
Standard 1	SC.912.N.1.	X																				
Physical Science																						
Standard 10	SC.912.P.10.	X			X																	
Mathematics Standards		MAFS.912.N-Q.1.1, MAFS.912.A-REI.2.3																				

Science–Standard 1: The Practice of Science

- SC.912.N.1.1- Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following: 1) pose questions about the natural world, 2) conduct systematic observations, 6) use tools to gather, analyze, and interpret data, 7) pose answers, explanations, or descriptions of events, 8) generate explanations that explicate or describe natural phenomena (inferences), 9) use appropriate evidence and reasoning to justify these explanations to others, 10) communicate results of scientific investigations, and 11) evaluate the merits of the explanations produced by others.

Science–Standard 10: Energy

- SC.912.P.10.1 - Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.
- SC.912.P.10.4 - Describe heat as the energy transferred by convection, conduction, and radiation, and explain the connection of heat to change in temperature or state of matter.

Mathematics–Numbers & Quantity

- MAFS.912.N-Q.1.1 - Use units as a way to understand problems and to guide the solution of multi-step problems; chose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

Mathematics–Algebra

- MAFS.912.A-REI.2.3 - Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

National Next Generation Science Standards

Energy

- HS-PS3-1 - Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other components and energy

flows in and out of the system are known.

- HS-PS3-3 - Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Engineering Design

- HS-ETS1-2 - Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Note: Related Common Core Mathematics Standards are listed in the Florida section above.

What's Cooking 2

- Record your results in the data table below. Fill in the first column with the types of containers you tested. To calculate the heat gain, use the formula:

$$Q = m C \Delta T$$

Where:

- Q = heat gain/loss
- m = mass in Kg units
- C = the specific heat value
- ΔT = the change in temperature
-

Specific heat of common substances	Specific heat J/Kg - K
air	101
aluminum	897
brass	376
copper	385
glass	840
iron	450
tin	227
water	4180

Type of solar cooker used in experiment _____

Container type	Temp (start)	Temp (30 min)	Calories of Heat Gain
Control (air in box oven)			

2. Did the water in any containers reach the same temperature as the air in the solar cooker? Why do you think this is occurred?

3. Which one of your containers increased the temperature of the water the best?

What reasoning supports this result?

4. How much heat energy was absorbed in the container of water that heated up the most? Use the equation $Q = m C \Delta T$ where C is the specific heat of water. (Note: 100 ml of water = 100 g of water – change g to kg before solving this problem). Show your work.

5. How much heat energy from the Sun was absorbed in the air of the cooker? Use the equation $Q = m C \Delta T$ where C is the specific heat of the air. (Note: To find the mass of the air – at the average density of 1.1 kg/m^3 for air in the temperature range of this experiment – find the approximate volume of air inside the cooker in cubic meters and multiply this value by 1.1 to get the air's mass in kg.) Show your work.

6. Which container acted as the best conductor and the best insulator of the heat transferred by the Sun and air in the cooker?

How do you know?

What's Cooking 2

For the problems below, use the formula for heat gain and the values for specific heat listed below.

$$\text{(Heat gain/loss) } Q = \text{mass (C) } (\Delta T)$$

Where C is the specific heat of a substance.

Specific heat of common substances	Specific heat J/Kg - K
aluminum	897
brass	376
copper	385
glass	840
iron	450

1. How much heat must be added to these cooking containers, each made of 5 kg of material to raise their temperatures from 25° C to 100° C?
 - a) aluminum
 - b) brass
 - c) copper
 - d) glass
 - e) iron

2. Which container from the question above would heat up faster?

3. 1 kg of 25° water is put in each container from question 1. The containers are placed in ovens that reached 125° C (and remain at that temperature for several hours). In what order would the water in the containers boil?

4. A 1 kg mass of metal absorbs 5775 J of heat when its temperature changes from 20° C to 35° C. Calculate the specific heat of the metal. Can you identify the metal based on the specific heat values in the chart above?