Introduction to Energy: Engineering Solar Ovens

*Energy Science course* (semester elective)

Harmony School, Bloomington, Indiana

Grades 7-10

**Objective**

Students will be introduced to the concepts of energy and thermodynamics by using an engineering design process to build, test and evaluate solar ovens.

**Learner Outcomes**

Students will be able to:

- Explain various forms of energy and give examples of how they can be transformed.
- Understand how the First Law of Thermodynamics relates to cooking food.
- Identify problems associated with traditional sources for cooking heat, as well as advantages and disadvantages of using solar energy for cooking heat.
- Describe how solar energy can be used in our everyday lives and homes.
- Describe heat transfer and the relationship among radiation, convection, conduction, absorption and insulation.
- Describe light energy and the relationship among transmission, reflection and refraction.
- Predict how various materials interact with light and heat energy.
- Create a diagram of energy transformations.
- Use an engineering design process to create, test and revise a prototype.
- Construct a solar cooker that fully cooks a food of the students’ choice.

**Lesson Overview**

<table>
<thead>
<tr>
<th>Session</th>
<th>5E</th>
<th>Description</th>
<th>STEM Disciplines</th>
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<tbody>
<tr>
<td>1</td>
<td>Engage</td>
<td>Introduction to heat and light</td>
<td>Physics</td>
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<td></td>
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<td>Present design challenge</td>
<td>Engineering</td>
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<td>Exploration</td>
<td>Field trip to passive solar home</td>
<td>Environmental Science</td>
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<td>3</td>
<td>Explanation</td>
<td>Design solar ovens</td>
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<td>Geoscience</td>
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<td>Exploration</td>
<td>Build solar ovens</td>
<td>Engineering</td>
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<td>5</td>
<td>Elaboration</td>
<td>Test and revise prototypes</td>
<td>Engineering</td>
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<td>Graph and analyze data</td>
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<td>6</td>
<td>Evaluation</td>
<td>Cook with solar ovens</td>
<td>Engineering</td>
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<tr>
<td></td>
<td></td>
<td>Assess oven design</td>
<td>Environmental Science</td>
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Next Generation Science Standards

**Physical Science: Energy**

- 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.

**Science and Engineering Practices**

- HS-ETS1-1: Asking Questions and Defining Problems
- HS -ETS1-2: Engaging in Argument from Evidence
- HS -ETS1-3: Analyzing and Interpreting Data
- HS -ETS1-4: Developing and Using Models

**Earth and Space Sciences**

- HS-ESS3-2: Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

**Disciplinary Core Ideas**

- PS3.A: Definitions of Energy
- PS3.B: Conservation of Energy and Energy Transfer
- ETS1.A: Defining and Delimiting Engineering Problems
- ETS1.B: Developing Possible Solutions
- ETS1.C: Optimizing the Design Solution

**Cross-Cutting Concepts**

- Systems and Systems Models
- Energy and Matter

**Materials**

Total cost for 32 students (8 groups of 4) = $566

See attached supply spreadsheet

- **Harmony Solar Oven Challenge worksheet packet**
- **Reflection/Refraction** (aluminum foil, reflective plastic, silver paint, silver duct tape, mirrors, magnifier)
- **Insulation** (cardboard boxes, foam insulation, newspaper, packing peanuts)
- **Construction** (white glue, glue guns, scissors, utility knives, rulers, pencils, paint brushes, rubber bands)
- **Absorption** (black paper, black paint, black duct tape)
- **Transmission** (plexiglass, oven bags, plastic wrap)
- **Measurement** (thermometers, timers)
- **Cooking** (aluminum or iron cookware, jars, tin cans, plastic bottles, oven mitts, food - rice, flour, marshmallows, etc.)
Daily Lesson Plans

Session 1 (1 hr.)

Introduction to Energy (15 min)
* Define energy.
* Ask the class to brainstorm a list of different forms of energy
* Discuss the idea energy can be transformed from one type to another
* Introduce First Law of Thermodynamics

Energy and Cooking (20 min)
* Ask students to describe various ways to use heat to cook food.
* Bring students to the board to help create a diagram of energy conversions during the cooking of food.
* Discuss the problems with many traditional ways of cooking.
  o Electric stoves use coal-generated power
  o Gas stoves emit greenhouse gases CO₂ (and some methane)
  o Firewood use leads to deforestation
  o Burning biomass releases carcinogens and other toxic fumes.
  o Collecting firewood is laborious/ fuel can be relatively expensive to many people in the world
  o Health implications of not having adequate cooking fuel:
    ▪ Contaminated drinking water kills 3.4 million people annually
    ▪ Risks associated with women/girls searching for fuel
* Explain the amount of solar energy available on Earth each hour, compared to our use of other forms of energy
  o 4.3x10^20 Joules per HOUR from incident solar energy VS.
  o 5.1x10^20 Joules per YEAR (2012) annual consumption!
* Show YouTube videos:
  o Cooker design company in Hong Kong http://youtu.be/cdccGqpcNRw
  o Darfur refugees avoid sexual harassment http://youtu.be/Dn2v6fJTl2s

Solar Oven Challenge (20 min)
* Present challenge to class and allow for some preliminary brainstorming and questioning as a whole class.
  o What are potential applications for solar ovens?
    ▪ Backpacking, natural disasters, refugee camps, space
  o Where in the world do solar ovens have the greatest potential?
    ▪ Tropical latitudes, deforested/desertified regions (no woodfuel)
  o Who is likely to benefit from solar ovens?
    ▪ Those that collect firewood, cook with firewood, live in areas with no electricity/off-grid, spend a large portion of income on fuel, live in areas with contaminated water
* Create teams (3-4 in a group) to discuss ideas and research oven designs using classroom computers.

Prepare for Field Trip (5 min.)
* Regroup students to discuss logistics and objective of field trip
Session 2 - Field Trip (2 hrs.)

Visit as many of the following locations as possible in the available timeframe:
- greenhouse
- passive solar home
- home with solar collector
- home with solar hot water heater
- business that installs or builds passive solar technologies

* Home owner (or installing plumber) to explain how the home/collector uses different materials for absorption, conduction, convection and insulation of radiant solar energy.
* Owner explains reasons for building/installing passive solar system (cost, greenhouse gas emissions, local solar window, rebates/tax subsidies).
* Students will identify flow and transfer of energy in the greenhouse/home/collector and relate to the First Law of Thermodynamics.

Session 3 (1½ hrs.) “DAY 1” in student packet

Review field trip and passive solar technologies for the home (5 min)

Heat and Light Energy (25 min.)
* Define for students the following terms related to light energy, using examples or demos where appropriate (laser pointer, flashlight, prisms, mirrors):
  - transmission
  - reflection
  - refraction
* Define for students the following terms related to heat, using examples or demos where appropriate (hot water, copper pipe, candle, teabag, metal and wooden spoons):
  - radiation
  - absorption
  - conduction/insulation
  - convection

Solar Oven Design (60 min.) “DAY 1” in student packet
* Distribute worksheet packet for guidance. Allow students to ask questions and clarify expectations and specifications.
* Students group into teams to share ideas and continue online research of design plans.
* Teams draft design plans.
* Teams choose recipes.
* Teams generate supply lists and may start gathering materials.
* Collect worksheet packets, checking for design plans, supply lists and recipe information.
Session 4 (45 min.) “DAY 2” in student packet

Review Concepts (10 min)
* Review vocabulary while presenting construction materials available to students. Ask students to identify materials that will transmit, reflect or refract light, and will absorb, transmit, conduct/insulate heat.

Solar Oven Construction (35 min)
* Review safety and clean-up procedures for utility knives, paint and brushes, etc.
* Go over design plans of each group before they begin construction.
* Students work with teams to build ovens.

Session 5 (45 min.) “DAY 3” in student packet – SUNNY WEATHER NECESSARY!

Solar Oven Test (20 min)
* Students finish final construction on oven prototypes.
* Students set-up ovens with 250mL water and oven thermometers.
* Students use timers to record temperature on worksheet every 3 minutes.

Solar Oven Analysis (20 min)
* Students use Google Spreadsheets to plot time vs. temperature data
* Teams analyze their data and the performance of their oven.
* Teams adjust and revise oven designs for cooking usage.

Prepare for Solar Cooking (5min)
* Collate teams’ data to discuss overall patterns/trends in the data and possible causes.
* As a class, analyze the graphs generated by the tests.
* Discuss the problems and solutions various groups encountered.
* Have teams organize themselves for cooking the next day (one person to set up oven, one person to check at lunch, etc.)

Session 6 (45 min) “DAY 4” in student packet – SUNNY WEATHER NECESSARY!

Solar Cooking (20 min)
* Before school, meet with students in kitchen to prepare ingredients and set-up ovens.
* At the lunch break, meet with students to reposition and check on ovens.
* At class time (2:00 PM), bring in ovens and serve food.
* Identify lessons learned and adjustments made during the cooking process.
* Clean up!!!

Solar Oven Evaluation and Energy Diagram (20 min)
* Allow students to eat food while working in groups to work on energy diagrams and evaluation (to be completed for homework).
Assessments
• Verbal check-ins for understanding through open-ended questions during class discussions, and with individuals during group work time.
• Worksheet packet to be assessed throughout the design process.
• Solar ovens to be displayed with energy diagrams at Science Expo later in school year
• Evaluation essay submitted online for comments and grading.
• Test on Laws of Thermodynamics and energy transfers at conclusion of unit.

Resources
- http://solarcooking.org/plans/
- http://www.solarcookers.org/
- http://journeytoforever.org/sc.html
- http://solarcooking.wikia.com/wiki/Classroom_resources
- http://www.re-energy.ca/solar-oven-challenge/recipes
DESIGN CHALLENGE

Design an efficient solar cooker that will reach the hottest temperature in the shortest amount of time.

- Heat water to 60°C (to pasteurize disease-causing microbes)
- Heat water to 100°C (to cook food with steam)
- Heat water to 175°C (to bake food)

INSTRUCTIONS

DAY 1

- Review examples of solar ovens and discuss how each type might work, advantages/disadvantages of each design.
- Design your oven – create a detailed, labeled diagram of your plan.
- Select a recipe to prepare in your oven.

DAY 2

- Identify and prepare the vessel you will use to heat water/food in your oven.
- Construct shape out of cardboard/foam.
- Coat interior and exterior with paper/paint/foil.

DAY 3

- Position water vessel and thermometer into oven.
- Test oven for 15 minutes in full sun; record and graph data.
- Assess prototype, redesign and improve oven.

DAY 4

- Before school, prepare food ingredients and set up oven.
- At lunchtime, check on and adjust position of oven.
- During classtime, serve and eat cooked food!
- Write an evaluation of your solar oven design.
- Create an energy diagram for your oven.
PLAN FOR YOUR SOLAR OVEN

Specifications:

* Must be able to hold 250 mL of water and oven thermometer.
* Must be able to remain upright and stable in outdoor field for 6 hours.
* Be reusable and cost-effective.
* Include materials for light transmission/refraction/reflection, heat absorption/conduction, insulation.
RECIPE FOR SOLAR COOKING

FOOD: ______________________________ http://www.re-energy.ca/solar-oven-challenge/recipes
Ingredients:

Cooking Directions:

SOLAR OVEN MATERIALS

List the supplies you use to construct your oven, and their approximate costs.

<table>
<thead>
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<th>Item</th>
<th>Quantity</th>
<th>Cost</th>
<th>Notes</th>
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<td>TOTAL COST</td>
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## SOLAR OVEN TEST

### Day 3

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<th>Temperature (Celsius)</th>
<th>Notes</th>
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<td>3:00</td>
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<td>9:00</td>
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<tr>
<td>12:00</td>
<td></td>
<td></td>
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</tbody>
</table>

↑ *Graph these data using a Google Spreadsheet*

Describe the results of your test:

List specific strengths of your design:
- ✪
- ✪
- ✪

List specific weaknesses of your design:
- ✗
- ✗
- ✗

Describe any adjustments made to your oven and rationale:
SOLAR OVEN ENERGY DIAGRAM  Day 4

Draw at least two views of your solar cooker (bird’s eye/cross-section/side/orthographic)
Indicate the following using arrows or waves:
* Heat energy (radiation/convection/conduction/insulation)
* Light energy (reflection/transmission/absorption)
Label everything!
Be neat: use a ruler, pencil and eraser, and large, clean sheets of paper.

SOLAR OVEN EVALUATION

Share your group’s evaluation of your solar oven using Google Drive.

* Describe in your own words how your oven transfers solar energy into cooked food. Explain how this demonstrates the First Law of Thermodynamics.
* How easy or simple is your solar oven to build? Approximate the cost to build the oven. Is this cost accessible to people in need of solar ovens?
* Identify and explain any problems or difficulties you encountered in using your solar oven to cook food. How did (or could) you solve them?
* What difficulties would you expect other people might encounter if they were relying on a solar oven for food or pasteurized water? How might they overcome them?
* In your opinion, what are the most important reasons or best uses of solar ovens? (For this question, each group member should contribute their own response.)
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<th>Category</th>
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<th>Qty.</th>
<th>Cost per</th>
<th>Total Cost</th>
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<tr>
<td><strong>Reflection/Refraction</strong></td>
<td>aluminum foil</td>
<td>8 rolls</td>
<td>$7.39</td>
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<td>reflective plastic</td>
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<td>silver paint</td>
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<td>silver duct tape</td>
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<td>jars, bottles, cans</td>
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<td>plastic wrap</td>
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<td>oven bags</td>
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<td>glue guns and sticks</td>
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<td>utility knives</td>
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<td>paint brushes</td>
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Describe the results of your test:

List specific strengths of your design:

✪
✪
✪

List specific weaknesses of your design:

✖
✖
✖

Describe any adjustments made to your oven and rationale:
**SOLAR OVEN ENERGY DIAGRAM**  

Day 4

Draw at least two views of your solar cooker (bird’s eye/cross-section/side/orthographic)

Indicate the following using arrows or waves:

- Heat energy (radiation/convection/conduction/insulation)
- Light energy (reflection/transmission/absorption)

Label everything!

Be neat: use a ruler, pencil and eraser, and large, clean sheets of paper.

---

**SOLAR OVEN EVALUATION**

* Share your group’s evaluation of your solar oven using Google Drive.

* Describe in your own words how **your** oven transfers solar energy into cooked food. Explain how this demonstrates the First Law of Thermodynamics.

* How easy or simple is your solar oven to build? Approximate the cost to build the oven. Is this cost accessible to people in need of solar ovens?

* Identify and explain any problems or difficulties you encountered in using your solar oven to cook food. How did (or could) you solve them?

* What difficulties would you expect other people might encounter if they were relying on a solar oven for food or pasteurized water? How might they overcome them?

* In **your** opinion, what are the most important reasons or best uses of solar ovens? (For this question, each group member should contribute their own response.)
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