THERMAL ENERGY Unit Overview

Energy is an overarching concept in all of science. In the past it has often been deemphasized or overlooked, and often not taught at all until high school. For this reason, teaching about energy may feel new and unfamiliar for many teachers.

Energy can be taught progressively and incrementally, spiraling throughout the middle school curriculum: first as thermal energy for the purpose of studying weather phenomena, then as energy of change related to chemical and physical changes, and finally in the form of kinetic and potential energy, related to the study of forces and motion. This unit covers the first of these — thermal energy.

Thermal energy transfer occurs in three ways: radiation, convection, and conduction. The first two of these are critically important to understanding weather phenomena — everything from how sunlight warms the Earth to how winds, precipitation, ocean currents, and extreme weather events occur. For this reason, **it is important to teach this unit before teaching weather and climate.**

This unit is centered around a solar cooker project. It begins with students observing a simple teacher-made solar cooker that only works moderately well. They model how it works to convert sunlight into thermal energy sufficient to cook food.

Students then learn about thermal energy and how it is transferred — radiation, convection, conduction (and its inverse, insulation) — then return to the solar cooker to design their own new improved cooker based on their new understanding of thermal energy. In the process, they learn about the Engineering Design Process. Students think about features that would improve the cooker; design, build, and test their cooker; and present their new understanding with a poster presentation. The final Exit Card asks students to explain their solar cooker design in terms of radiation, convection, and conduction. You could use this as a final assessment in conjunction with the poster presentation.

Because solar cookers are central to this unit, it is important to **do this unit at a time of year when the weather is reliably sunny**. At least the first lesson and the final project should be carried out during sunny weather. If you cannot depend on sunny weather, there are some suggestions in Lesson 1.

Lessons

Lesson 1: Solar Cooker
Lesson 2: Motion and Temperature (1-2 days)
Lesson 3: What is Heat?
Lesson 4: Radiation
Lesson 5: Different Roofs
Lesson 6: What is “Cold?”
Lesson 7: Conduction
Lesson 8: Where Does the Thermal Energy Go?
Lesson 9: Conduction: Amount of Matter
Lesson 10: Melting Ice
Lesson 11: Insulation
Lesson 12: The Icepop Challenge
Lesson 13: Convection
Lesson 14: The New Improved Solar Cooker (final project/ Performance Assessment, 3 days)
Review and Assessment

Materials

- ★ (for Lesson 1) 4 shoeboxes for teacher-made cooker and controls (one empty, one just lined with black paper, one just covered with plastic wrap)
- ★ shoeboxes for final project (1 per group)
- ★ black construction paper
- ★ plastic wrap
- ★ a variety of building materials (Suggested: cardboard, tape, foil, plastic wrap, fabrics, different colors of construction paper, newspaper, bubble wrap, wax paper, parchment paper, styrofoam sheets, thin sheets of cork) and other materials students bring in, subject to your approval
- ★ art supplies (suggested: poster paper, drawing paper, pens, pencils, markers)
- ★ balloons (1 per group, plus extras)
- ★ chart paper
- ★ plastic dice (1 per group, for Lesson 7)
- ★ glass marbles (1 per group, size is not important; for Lesson 7)
- ★ candle
- ★ several metal paper clips
- ★ cm rulers and meter sticks
- ★ manila folders to cut up for Lesson 5
- ★ scissors and box cutters
- ★ parabolic space heaters or other radiating space heaters (optional) — borrow 1 or more for Radiation lesson (NOT the kind that blow air; alternatively, you can use heat lamps)

Labware

- ★ beakers
- ★ Erlenmeyer Flask
- ★ tongs to hold flask, or oven mitts (for teacher)
- ★ metal weights (1 per group, any size, as long as it's metal; 50 g-1000g is an ideal range; for Lesson 7)
- ★ plastic bottles, 500mL are best, enough for all groups in a class
- ★ hot plates (1 per group and one for teacher; or boiling water from a kettle for teacher to fill groups' beakers)
- ★ heat lamps (ideally one per group, if available; if not, students can rotate through)
- ★ temperature probes (preferred) or thermometers (1 per group)
- ★ oven thermometers that read up to 200 °C or more (for each group, recommended, for lesson 14)
- ★ dropper or pipette
- ★ goggles

For optional conductivity demo:

- ★ metal rod (such as the kind found on a ring stand)
- ★ 1 or 2 ring stands to hold the metal rod horizontally (If you have more than 1 metal rod, you can set up multiple ones and compare their conductivity.)
- ★ bunsen burner (or candle)

Consumable Lab Supplies

- ★ 3 tea bags for each class
- ★ ice for groups and for demos
- ★ ice for convection demo (colored blue with food coloring if possible)
- ★ hot water
- ★ room temperature water
- ★ Icepops - 1 per group; buy enough for at least 2 classes if you teach multiple classes so there is time to refreeze them. (Buy brands that come in a sturdy sealed plastic pouch without a stick, and can be refrozen for reuse. These are usually found on the shelf, not in the freezer section) **OR: Use ice in baby food jars** instead; use a graduated cylinder to measure the meltwater)
- ★ food coloring— preferably red and blue
- ★ food to cook inside the cooker (tortillas and shredded cheese to make a quesadilla, English muffins with sauce and cheese to make mini pizzas, cookie dough, etc. Check for allergens if this is an issue. Small amount for Lesson 1, more for Lesson 14. For Lesson 14, each group should have the same item, same size, to cook so it is a fair comparison.

Other Supplies

- ★ Computer to project simulation of particle motion (can also be assigned as an Extension in Lesson 2)
- ★ Video clip or graphic of the electromagnetic spectrum (optional, for Extension)
- ★ Ice Melting Blocks (for Lesson 12 alternate exit card demo)

For optional demonstration in Lesson 2:

- ★ tennis balls or ping pong balls (at least a dozen, can be borrowed)
- ★ wire bin (preferable) or clear plastic bin

Advance Preparation

- ★ (for Lesson 1) Set up the solar cooker and controls for demonstration
- ★ (for Lesson 13) Make some blue ice cubes ahead of time by adding 1-2 drops of blue food coloring to the water in each cube in the tray. (Regular ice cubes will work as well; blue ones are just more dramatic. If ice is not available, you can skip it since the emphasis is on warm matter rising.)
- ★ (for final project) Gather materials that students could use to build their solar cookers, including plenty of cardboard and cardboard boxes

★ (for various lessons) Gather empty plastic bottles for various labs: several 500mL bottles (enough for each group)

Vocabulary

Temperature
Energy: Light energy, Thermal energy, Kinetic energy
Model
Particles/molecules
Electromagnetic waves
Radiation
Convection
Energy Transfer
Conduct / conduction / conductor
Insulate / insulation / insulator
Control, variable
Procedure
Conclusion
Data
Evidence
Design
Feature

THERMAL ENERGY Unit
Next Generation Science Standards

Next Generation Science Standards - Performance Expectations	
MS-PS3-3.	Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.
MS-PS3-4.	Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.
MS-PS3–5.	Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
MS-ETS1-1.	Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
MS-ETS1-2.	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
MS-ETS1-3.	Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
MS-ETS1-4.	Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Planning and Carrying Out Investigations Constructing Explanations and Designing Solutions Engaging in Argument from Evidence ————————————	**PS3.A:** Definitions of Energy **PS3.B:** Conservation of Energy and Energy Transfer **ETS1.A:** Defining and Delimiting an Engineering Problem **ETS1.B:** Developing Possible Solutions	Scale, Proportion, and Quantity Energy and Matter

Connections to Nature of Science Scientific Knowledge is Based on Empirical Evidence		

California Common Core State Standards Connections:

ELA/Literacy –

RST.6–8.1	Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
RST.6–8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
WHST.6–8.1.a–e	Write arguments focused on discipline-specific content.
WHST.6–8.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Mathematics –

MP.2	Reason abstractly and quantitatively.
6.RP.1	Understand the concept of ratio and use ratio language to describe a ratio relationship between two quantities.
6.SP.5.a-d	Summarize numerical data sets in relation to their context.