National Aeronautics and Space Administration

Investigating Physics

Feel the Heat

5E Lesson Plan

Source Material: Feel the Heat

Mission Focused Area: Earth's Moon

Lesson Overview

Middle school engineers will use a liquid passing through tubes to collect heat energy from a source location and move it, just like the heat rejection engineers working on the Curiosity and Perseverance rovers. After brainstorming ideas and building their design, students will have to test their designs to see how well they work. The criterion for success in this case is to capture a measurable amount of heat from the lamp into the liquid. The more heat captured, the better the design. Students will have to optimize their design in order to allow the liquid to capture as much heat as possible.

NASA Connection

Extreme temperatures are one of the five hazards of human spaceflight. To survive long stays on the Moon, astronauts will need buildings that can protect them from the Moon's frigid temperatures—temperatures that are nearly twice as cold as Antarctica. One way to heat a building is to use the Sun. Some places near the Moon's poles get nearly constant sunshine. This steady supply of sunlight can be used to heat water. Once you have hot water, it can be pumped through a building to heat it.

Objectives

- Students design and build a solar water heater using household materials
- Students evaluate and refine their solar water heater design
- Students explain the functioning of their solar water heater using the laws of thermodynamics

Guiding Questions

- How might astronauts use a solar water heater?
- Where did conduction, convection, and radiation occur in your water heater?
- Which features help a solar hot water heater use solar energy (light and infrared radiation) to heat water?
- Engineers' early ideas rarely work out perfectly.
- How does testing help improve a design?
- How do the stories on the back of the handout about explore the Moon relate to the activity?

National STEM Standards

NGSS

- **HS-PS3-4** Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

5E Instructional Model

Materials

- 2 paper cups – medium size (per heater)
- 3 feet (0.9 m) clear plastic tubing – outside diameter: ¼ inch (6mm) (per heater)
- Large sheet of cardboard – e.g., 11 x 17 inches (28 x 43 cm) (per heater)
- Aluminum Foil
- Black Marker
- Black Paper
- Pitcher of water
- Ruler
- Scissors
- Straws
- Duct Tape
- Gooseneck Lamp with an indoor 100-watt floodlight light bulb – optional if using sunlight
- An indoor-outdoor digital thermometer that can read tenths of a degree
- Student Challenge Sheet

Teacher Action

Engage - Brainstorm Session

- Use the verbiage from the source material under “Introduce the challenge” and the student handout to set the stage for students
- Gather student ideas onto a poster or whiteboard
- Ask students to make observations about the sample solar water heater in regard to its physical characteristics (color, shape, etc.)
- Scripted CFU questions
- What challenges do future astronauts on the Moon need to prepare for?
- Where will astronauts get their energy when living and working on the Moon?

Explore - Design and Build Solar Water Heater

- Review how to use a digital indoor-outdoor thermometer to measure the before and after temperature of the water with students
- Scripted CFU questions
- What color should you make the tube and background?
- Being exposed to light is what heats water. How fast do you want water to flow through the tube?
- How can the way you zigzag the tube across the cardboard help the water in the tube absorb heat from the Sun or light bulb?

Explain - Written explanation of results

- Provide students with a common set of terms, the laws of thermodynamics in this case, and instruct them to construct a written explanation of the results of the test
- Check student answers and facilitate sharing of the responses

Scripted CFU questions

- Where did conduction, convection, and radiation occur in your water heater?
- Describe the change in entropy in the water and in the system as a whole

Elaborate - Evaluate and improve design

- Model use of materials to add or remove components to the designs
- Ask students: How can you get a bigger temperature change?
- Facilitate student work while they redesign and retest their solar water heaters

Scripted CFU questions

- How might astronauts use a solar water heater?
- Which features help a solar hot water heater use solar energy (light and infrared radiation) to heat water?
- Engineers’ early ideas rarely work out perfectly. How does testing help improve a design?

Evaluate - Engineering Design Rubric

- Assess student designs using the rubric included in the source material

Student Action

Engage - Brainstorm Session

- Make observations and brainstorm ways to heat water using solar energy with the help of the teacher example solar heater

Explore - Design and Build Solar Water Heater

- Following procedures on student handout; design, build, and test a solar water heater
- Take measurements using the thermometer, make observations, and take notes on the performance of the device

Explain - Written explanation of results

- Use the laws of thermodynamics to develop a written explanation for the results of the initial test

Elaborate - Evaluate and improve design

- Redesign portions of the solar water heater in attempts to get a bigger temperature change
- Lengthen tube, add turns, change the color of the background, etc.

Evaluate - Engineering Design Rubric

- Present solar water heater design to teacher