

FEEL THE HEAT

LEADER NOTES

The Challenge

Design and build a solar hot water heater and see how big a temperature change you can get.

In this challenge, kids follow the engineering design process to: (1) build a solar hot water heater; (2) test to see if it can raise the temperature of water; and (3) use their testing results to improve their heater and get as big a temperature change as possible.

1 Prepare ahead of time

- Read the challenge sheet and leader notes to become familiar with the activity.
- Gather the materials listed on the challenge sheet.
- Build a sample hot water heater.
- The activity takes from 1 ½ to 2 hours.
Decide where to store kids' hot water heaters, if necessary.
- Decide whether you will use natural sunlight or a lamp to heat the hot water heaters.

2 Introduce the challenge (5 minutes)

- **Tell kids how NASA might use solar-powered heating on the moon.**

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.

- **Show kids your sample hot water heater.**

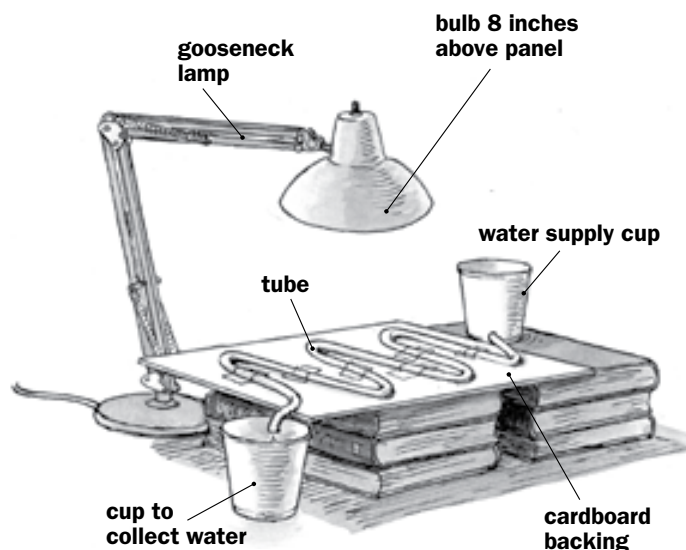
This is one kind of hot water heater. The water starts up here in the water-supply cup, flows down through the tube (thanks to gravity), gets warmed on the panel, and then flows out the end of the tube into a collection cup. This is just one way to make a hot water heater. You may want to make changes to this design to make it work better. Improving a design based on testing is called the engineering design process.

3 Brainstorm and design (10 minutes)

Distribute the challenge sheet. Discuss the questions in the Brainstorm and Design section.

SAFETY NOTE

If you use a lamp, keep the cord and bulb away from the water. To keep the lamp base far away from the hot water heater, use a gooseneck lamp. This kind of lamp also makes it easy for kids to keep the light bulb 8 inches above the hot water heater.



Sample solar hot water heater

- **What color should you make the tube and background?** (*Remind kids that the color black absorbs heat energy well and that white reflects it.*)
- **How fast should the water flow through the tube? How might its speed affect its temperature?** (*The more time water has to absorb heat energy, the warmer it will get. Kids can give water more time to absorb heat energy by slowing the flow.*)
- **How can zigzagging the tube help the water absorb heat from the sun or light bulb?** (*The longer light shines on the water in the tube, the warmer the water will get. If kids run the tube so most of it lies where the light is strong, the water will absorb more heat.*)

HOW TO MEASURE THE CHANGE IN WATER TEMPERATURE

Review how to use a digital indoor-outdoor thermometer to measure the before and after temperature of the water. The sensor at the end of the long wire is the “outdoor” part of the thermometer. Dip it into the pitcher of cold water. Wait one minute or until the “outdoor” display stops changing. Record this “before” temperature. Turn on the lamp and position it eight inches above the hot water heater. Fill the supply cup with water from the pitcher. As it trickles out the end of the tube into the collection cup, hold the tip or the wire in the stream of water. Tell kids not to touch the tip—heat from their hands will affect the reading. Record this “after” temperature. By comparing it to the “before” temperature, kids can calculate the increase in water temperature.

4 Build, test, evaluate, and redesign (60 minutes)

Help kids with any of the following issues. For example, if:

- **water leaks**—*Add more tape to the junctions or redo them.*
- **kids forget how to measure temperature change**—*Kids should record the temperature of the water in the pitcher. They then should pour water from the pitcher into the supply cup at the top of the heater and measure the temperature just as it flows out of the tube.*
- **there is little temperature change**—*This means the water needs to spend more time in the light. Have kids put more of the tube where the light is the strongest, make the tube longer, or slow down the water flow. Also, suggest that they color the tubes black or put a piece of black paper behind the tube to absorb more heat energy.*
- **the tube isn't long enough**—*Make the tube longer by attaching two or three together.*
- **water runs through the tube too quickly**—*Change how fast the water flows. Pinch the tube with tape or paper clips. Also, check the height of the water supply cup. The higher it is above the end of the tube, the faster the water will flow. To slow the flow, move them so the two cups are nearly at the same height.*

5 Discuss what happened (10 minutes)

Have the kids show each other their heaters and talk about how they solved any problems that came up. Emphasize the key ideas in today's challenge by asking:

- **How might astronauts use a solar water heater?** (*Solar hot water heaters can heat water for daily use. The hot water can also be used to heat lunar outposts, greenhouses, and other structures.*)
- **Where did conduction, convection, and radiation occur in your water heater?** (*Conduction occurred where the tube was in direct contact with the warm panel and heated air molecules. Convection occurred when the warm solar panel [and light, if one was used] heated the air, making it less dense and causing it to rise. Radiation occurred when heat was transferred from the heat source via infrared radiation and light.*)

- **Which features help a solar hot water heater use solar energy (light and infrared radiation) to heat water?** (Key features include: large surface area angled to face the light, black color, thin tubing for efficient heat absorption, transparent cover to minimize heat loss, and insulation.)
- **Engineers' early ideas rarely work out perfectly. How does testing help them improve a design?** (Testing helps you see what works and what doesn't. Knowing this lets you improve a design by fixing the things that aren't working well or could work even better.)
- **How do the stories on the back of the handout about exploring the moon relate to today's activity?** (Kids learn how cold it is on the moon and how NASA uses sunlight to generate electricity.)

EXTEND THE CHALLENGE

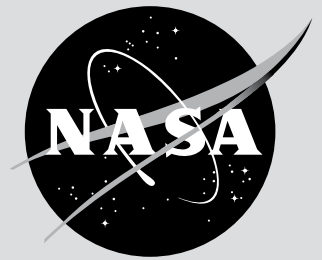
- **Concentrate the light to get the water hotter.** Have kids use file folders and aluminum foil to make panels that can reflect and concentrate light. Have kids attach their reflectors to their hot water heaters. Calculate the average temperature change of the group's hot water heaters.
- **Connect hot water heaters in a series.** After kids succeed with their individual hot water heaters, connect several together. Does letting the water run through several solar hot water heaters heat the water a lot more than when it runs through just one?
- **Make a solar cooker!** Have your kids use the engineering design process to make a solar cooker and cook marshmallows for hungry astronauts. Find this activity at: pbs.org/wgbh/nova/teachers/activities/3406_solar.html.
- **Watch a PBS show about solar energy.** View the PBS NOVA program *Saved by the Sun*. It outlines innovative ways that solar energy is being used to provide heat energy and power. It is streamed online at: pbs.org/wgbh/nova/solar/.

CURRICULUM CONNECTIONS

Feel the Heat ties to the following concepts commonly covered in science, math, and technology curricula. For a list of education standards supported by the activity, see pages 42 and 43.

- **Heat transfer**—Heat is transferred from the sun/lamp to the tube by radiation (i.e., infrared waves—see below). The tube transfers its heat to the water by direct contact (i.e., conduction).
- **Infrared radiation**—It is the infrared part of the electromagnetic spectrum coming from the light/sun that changes the water temperature.
- **Converting light to heat energy**—Some shapes, colors, and materials are particularly good at absorbing light energy and releasing it as heat energy.
- **Gravity-fed water systems**—Gravity pulls the water through the solar panel's tube when the supply cup is placed higher than the collection cup.
- **Measurement**—Kids measure the volume of water, the temperature change, and the rate of water flow.

FEEL THE HEAT



Colder than Antarctica? Welcome to the moon! To survive on the moon, astronauts will need buildings that can protect them from temperatures as low as -250° Fahrenheit (-157° Celsius). One way to heat these buildings is to use sunlight to heat water and pump it through the rooms.

WE CHALLENGE YOU TO...

...design and build a solar hot water heater and see how big a temperature change you can get.

BRAINSTORM AND DESIGN

To heat water with your heater:

- 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?

BUILD

- 1. First, get water to flow through the tube.** Poke a small hole near the bottom of a cup. Put the tube into the hole. Set a second cup under the tube's other end. Test your system with water. Seal any leaks.
- 2. Then, build your hot water heater.** Use the materials to design a system that can help the water absorb a lot of heat energy.

TEST, EVALUATE, AND REDESIGN

- Put your heater in strong sunlight or 8 inches (20 cm) below the lamp. (SAFETY NOTE: Keep water away from the outlet, lamp, and bulb.)
- Measure and record the temperature of the water in the pitcher.
- Pour water from the pitcher into the supply cup.
- Record the temperature of the water as it comes out of the lower end of the tube.

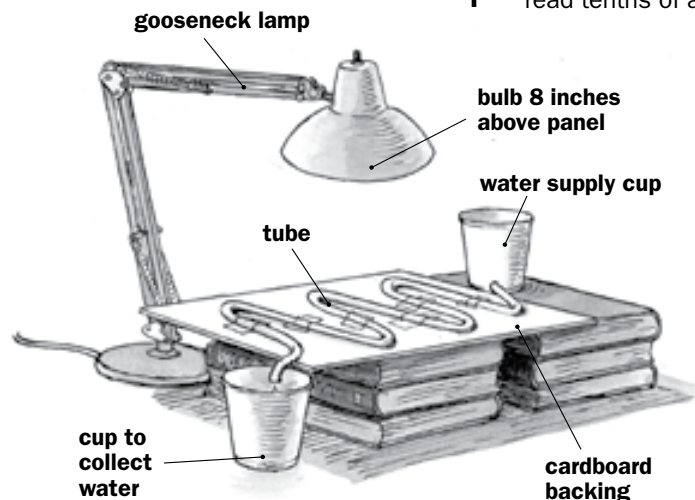
Starting temperature: _____

Ending temperature: _____

Temperature change: _____

MATERIALS (per heater)

- aluminum foil
- large sheet of cardboard (e.g., 11 x 17 inches / 28 x 43 cm)
- gooseneck lamp with an indoor 100-watt floodlight light bulb (optional if using sunlight)
- black marker
- black paper
- 2 paper cups (medium-sized)
- 3 feet (0.9 m) clear plastic tubing (Outside diameter: $\frac{1}{4}$ inch / 6 mm)
- pitcher of water
- ruler
- scissors
- straws
- duct tape
- an indoor-outdoor digital thermometer that can read tenths of a degree



TEST, EVALUATE, AND REDESIGN (CONTINUED)

Can you get an even bigger change? Engineers test a design and improve it based on what they learn. This is called the design process. See how big a change you get.

- **Help the water absorb more heat**—Add materials above, below, or around the tube to focus more heat energy on the water. Also think how you can use color to help heat the water.
- **Slow the flow**—The longer the water stays in the light, the more it will heat up. Figure out how to make the water flow slowly through the tube.
- **Make your tube longer**—A longer tube can help water stay in the light for a longer time. Tape two tubes together.
- **Air bubbles clog the tube**—Blow into the tube to clear it.

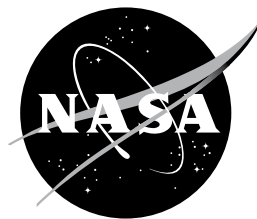
WHAT SHALL I WEAR?

Ever have trouble deciding what to wear? Try packing for the moon! On the moon, daily temperatures can swing about 500° Fahrenheit (260° Celsius). It can get up to 250° F (121° C) during the day, and at night, it can drop to -250° F (-157° C). Earth's blanket of air—the atmosphere—keeps us at a comfortable average temperature of 60° F (16° C).

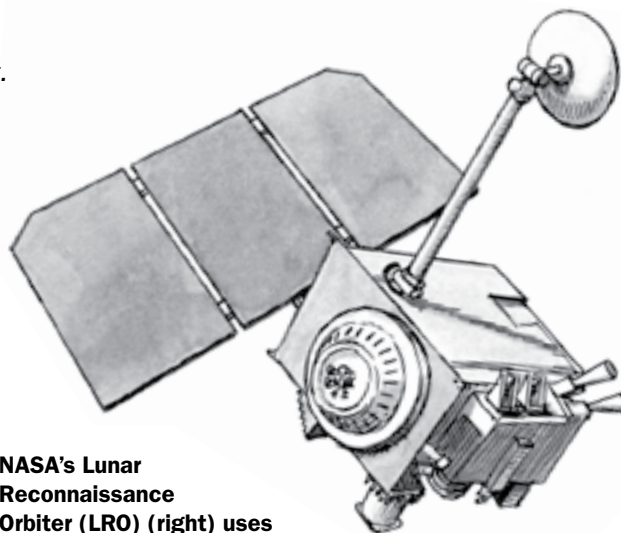
But the moon has no atmosphere to hold heat.

Better bring a well-insulated space suit when you visit!

Buzz Aldrin wore a million dollar spacesuit (left) designed to protect him from the moon's extreme hot and cold temperatures.



Check out NASA's moon missions at moon.msfc.nasa.gov.



NASA's Lunar Reconnaissance Orbiter (LRO) (right) uses a large solar panel to turn sunlight into electricity.

RUN BY THE SUN

Make your own electricity? In space, NASA's LRO spacecraft uses large solar panels to turn sunlight into electricity. They can produce about 1850 watts—enough to run a large microwave oven. But on average, LRO only uses 800 watts—enough to run a small toaster. The extra electricity is stored in batteries on board the LRO. When LRO goes into the shadow behind the moon, the darkness there prevents it from using the energy from the solar panels. So it powers itself with the batteries.

Watch **DESIGN SQUAD** on PBS or online at pbs.org/designsquad.



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