National Aeronautics and Space Administration

Educational Product	
Educators & Students	Grades 5–12

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Educational Brief

CASSINI SCIENCE INVESTIGATION

Sand or Rock: Finding Out From 1000 km

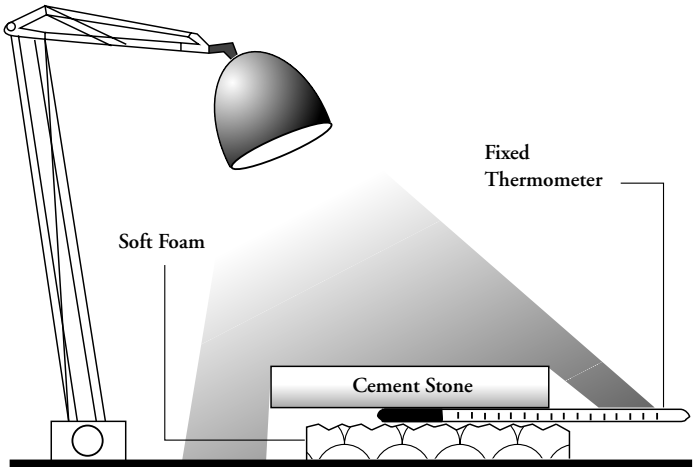
Objective

To observe the differences in thermal behavior between similar materials having different physical properties by making a series of temperature measurements and plotting the results.

Time Required: 3–6 hours

Saturn System Analogy: Remote sensing of thermal properties in the Saturn system

Keywords: Rock, Sand, Thermal Inertia, Thermal Infrared, Thermal Mass, Thermometer



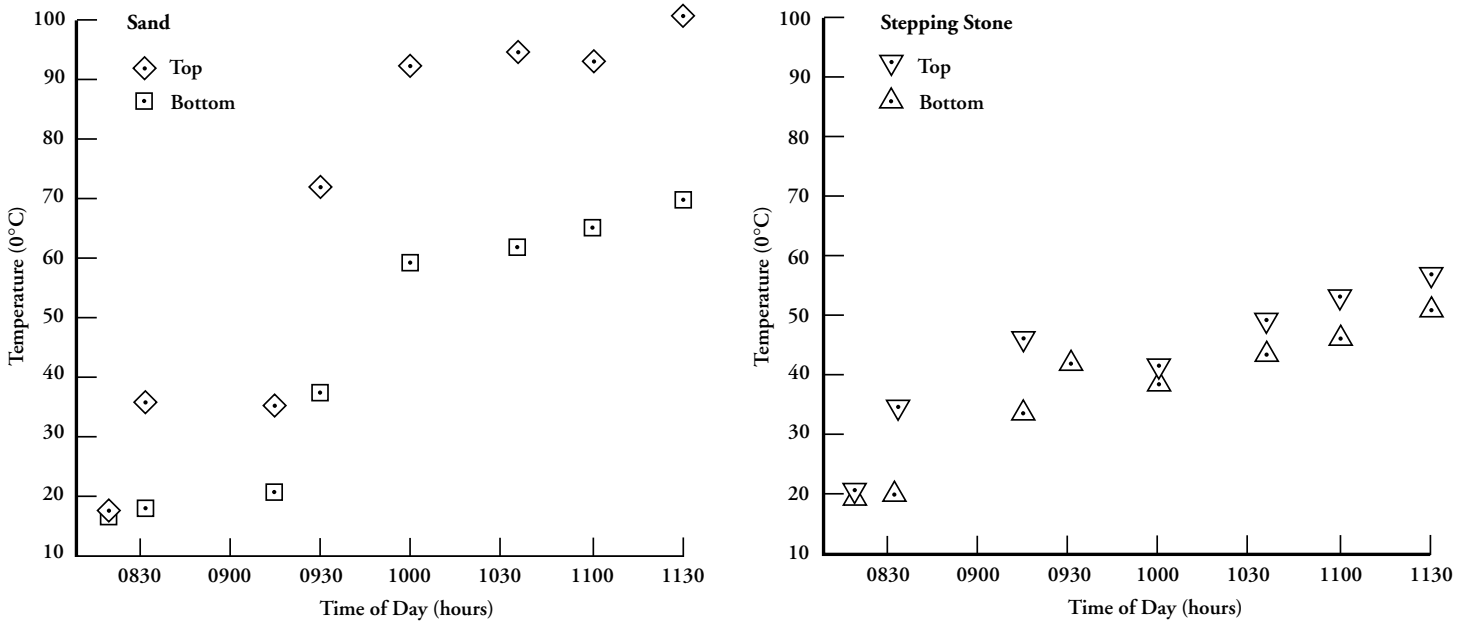
MATERIALS

- Cement stepping stone
- Loose sand with weight and color similar to that of the cement stone
- Cardboard to hold the sand in the same shape/size as the block (take-out pizza cartons may be particularly suitable)
- Four laboratory thermometers (that can be read to 1 °C)
- Scraps of foam rubber
- Optional: plastic bag
- Several hours of direct sunlight or two desk lamps (bulbs need to be of equal wattage)
- Notebook paper
- Graph paper

Discussion

Determining the physical characteristics of a surface from a long distance is not as difficult as it seems, given the right instrumentation. Spacecraft carrying instruments that operate in the thermal infrared (the portion of the electromagnetic spectrum sensed as heat that lies between visible light and radio waves) collect data that can provide strong evidence of the surface material type in the measured area.

Anyone who has visited a beach around sunset knows how fast the sand surface cools, but how it remains warmer underneath. Similarly, an unused fire ring that has been baking in the Sun during the day stays warm long after sundown. In this activity, students make measurements that illustrate the heating and cooling behavior of different materials.



Examples of thermal data recorded by a student. Some inconsistencies are apparent but the difference in thermal behaviors of the two materials is obvious.

Procedure

Start by constructing a cardboard tray with approximately the same shape and size as the stepping stone. The tray can be lined with a plastic bag to prevent leakage, if desired. Pour the sand into the tray, and place one thermometer bulb beneath the sand. The sand depth should equal the stone's thickness.

On the morning of the experiment, take the tray of sand and the stone and place both in an area that will receive direct sunlight through early afternoon. Place the thermometer bulb on top of a piece of foam rubber (so the thermometer won't be crushed), and then place the cement stone gently, in direct contact, on top of the thermometer. (On cloudy days, a pair of desk lamps, one for the sand and one for the stone can be used. Place the lamps equidistant from the centers of the tray of sand and the stepping stone.)

Next, place a thermometer on top of the cement stone and another on top of the sand. Hold the bulbs gently in contact with the surfaces using some foam rubber, and wait for the temperatures to stabilize. (For consistency, a book or some other weight can be used to hold the foam and thermometers in contact with the surfaces with the same force for each measurement.)

Make temperature readings of all four thermometers every 15 to 30 minutes, and record them for later plotting. (Read more or less frequently depending on the observed rate of surface temperature change.) Be sure to remove the surface thermometers between measurements so that insolation can continue, and remember that they need time to match the surface temperatures before those measurements are recorded.

In the afternoon, remove the sand and stone from the sunlight and record their temperatures as they cool down. Data recording can be shared among classes over the course of the day and combined later.

Thermal infrared recording instruments aboard spacecraft make similar measurements using remote sensing. By determining the wavelength (or frequency) of the peak of the black body curve of a surface, the temperature of that surface can be measured. It is more diagnostic to study the temperature behavior of a surface as it warms up from the cold of night, but measurements made after sunset are also

informative. The placement of the stone and sand in the morning sunlight mimics the sunrise on a planetary surface, and removing the samples from sunlight to let them cool down mimics sunset.

The shapes of the warming and cooling curves will be quite different for the two samples. The sand will warm and cool quickly on the surface. The cement stepping stone will warm slowly and not as much as sand, and it will retain its warmth much longer after sunlight is removed. We can draw the same conclusion when looking at planetary surfaces: slowly cooling surfaces are solid and rapidly cooling surfaces may be fragments or loose, sandy material.

Extension

Experiment with different sizes of material, including fine and coarse-grained sand and various grades of gravel. Also compare wet and dry materials. Examine the effect of the color and reflectivity (albedo) of different samples of sand, gravel, and stone too. Try good insulators, like styrofoam or foam rubber, and good conductors (large scraps of metal), like iron and aluminum.

Several vendors offer temperature sensors and software that allow data to be acquired, recorded, and plotted under computer control. Many spacecraft acquire all their data via computer control, and computerized data acquisition is common in many laboratories on Earth.

Noncontact infrared thermometers are available from several manufacturers at prices starting around $100. These sensors detect thermal infrared radiation (wavelength range of about 8 to 14 micrometers) and compute the temperature that would produce the amount of received infrared. Such a thermometer can be used instead of the surface-measuring laboratory thermometers described in this lesson, closely mimicking actual spaceflight measurements.

Science Standards

A visit to the URL http://www.mcrel.org yielded the following standards and included benchmarks that may be applicable to this activity.

12. Understands the nature of scientific inquiry.

LEVEL 1 (GRADES K–2)

Knows that learning can come from careful observations and simple experiments.

Knows that tools (e.g., thermometers, magnifiers, rulers, balances) can be used to gather information and extend the senses.

LEVEL 2 (GRADES 3–5)

Knows that scientific investigations involve asking and answering a question and comparing the answer to what scientists already know about the world.

Plans and conducts simple investigations (e.g., formulates a testable question, makes systematic observations, develops logical conclusions).

Uses appropriate tools and simple equipment (e.g., thermometers, magnifiers, microscopes, calculators, graduated cylinders) to gather scientific data and extend the senses.

LEVEL 3 (GRADES 6–8)

Designs and conducts a scientific investigation (e.g., formulates hypotheses, designs and executes investigations, interprets data, synthesizes evidence into explanations, proposes alternative explanations for observations, critiques explanations and procedures).

Establishes relationships based on evidence and logical argument (e.g., provides causes for effects).

LEVEL 4 (GRADES 9–12)

Designs and conducts scientific investigations (e.g., formulates testable hypotheses; identifies and clarifies the method, controls, and variables; organizes, displays, and analyzes data; revises methods and explanations; presents results; receives critical response from others).

Teachers — Please take a moment to evaluate this product at http://ehb2.gsfc.nasa.gov/edcats/educational_brief.
Your evaluation and suggestions are vital to continually improving NASA educational materials. Thank you.

Student Worksheet — Sand or Rock: Finding Out From 1000 km

Procedure

1. Pour sand into the box. Place one thermometer into the sand so it touches the box bottom.

2. Place the stepping stone and the box of sand in direct sunlight.

3. Place a thermometer on top of a piece of foam rubber. Lift the cement stone and gently lower it onto the thermometer that is on top of the foam rubber.

4. Place a thermometer on top of the stone and another on top of the sand. Hold them in contact by placing a piece of foam rubber on top, and then a book on top of the foam rubber.

5. Wait for the thermometer temperatures to stabilize and record all four temperatures.

6. Remove the top thermometers.

7. Repeat all four temperature readings every 30 minutes (or at a time interval specified by your teacher) and record the data.

8. Later in the day, remove the sand and stepping stone from the sunlight.

9. Continue to take temperature readings as they cool down.

10. Plot your temperature results on graph paper to see how the two materials respond to the thermal environment.

Time	Sand Top	Sand Bottom	Stone Top	Stone Bottom