Introductory Note:

In this activity, students will record and graph temperature data to learn about NASA's Mars Microprobe Mission, Deep Space 2, and how the properties of a material affect the transfer of heat. Unfortunately, the probes were not heard from after their arrival at Mars, but lessons can still be learned from them, for both space engineers and students.

Students will use a model of an ice-rich and ice-free near-surface on Mars to examine how the ice content of the Martian soil will affect the rate at which a warm probe will cool. This activity is designed to take advantage of high school laboratory equipment. However, it can easily be adapted for younger students and more common materials (as depicted in the photos). One 45-minute class period is required for the activity, plus an additional 45 minute class period if the students will make graphs in class. Younger students who have not been exposed to graphing can discuss the data qualitatively.

This activity was conceived and written by Dr. Mary Urquhart, a Caltech Postdoctoral Scholar at NASA's Jet Propulsion Laboratory and member of the Deep Space 2 science staff, and co-authored by Sally Urquhart, an environmental chemist and chemistry teacher at Lake Highlands High School in Dallas, Texas, Richardson Independent School District. For a more details on this experiment and some more advanced options, see http://lyra.colorado.edu/sbo/mary/mars/. For more about the Deep Space 2 Mars miniature probes, visit http://nmp.jpl.nasa.gov/ds2/ . For other space-related activities, see The Space Place web site for kids at http://spaceplace.jpl.nasa.gov.

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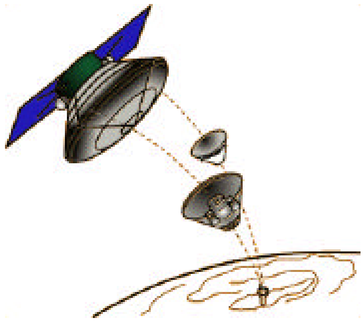


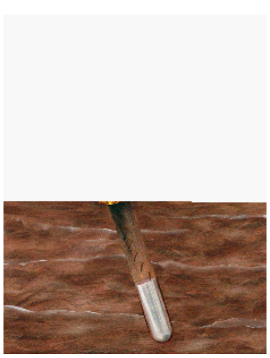
PROBING BELOW THE SURFACE OF MARS

Mars is a cold desert. Long ago, liquid water flowed on the surface of Mars. Today, water still exists on Mars, but what we can see is ice. The polar caps of Mars are at least part water ice, like those of the Earth. Telescopes and spacecraft can see a type of clouds made of tiny crystals of ice, called cirrus clouds, drifting in the atmosphere of Mars. Frost can even cover the surface of rocks and soil in the morning, much like it does on cold mornings in many places here on Earth. Scientists who study Mars see evidence that Mars had much more water in its past, at least on the surface. What happened to that water?

Some of the water is believed to be frozen in the Martian soil. Many regions on our own world have water frozen in the ground, either during the winter or, in very cold places, all year long. Water frozen in soil is simply called ground ice. If the ground ice remains throughout the year without melting, it is called permafrost**.** Permafrost is common in places like Siberia, northern Canada, and near the peaks of high mountains.

Mars is as cold, or colder, than the coldest places here on Earth. Any ground ice on Mars should stay frozen all year, and will be permafrost. However, finding the ground ice on Mars isn't easy. A dry layer of soil is believed to be on top of the icy soil, making it difficult to detect at the surface. One way to find the ice is to send a probe below the surface of Mars. Close to the poles, many Mars scientists think the dry layer of soil will be very thin, and the icy ground will be close to the surface. The Mars Microprobes were designed to land in just such a place.

On December 3, 1999, two tiny probes, encased in basketball-sized containers called aeroshells, arrived at Mars. Unfortunately, the probes did not report back to Earth as expected, so we're not sure how they fared. However, they were supposed to impact the surface of Mars near the south pole at a speed of about 720 km/hr (or 450 miles/hr). Upon impact with the surface of Mars, each aeroshell was to shatter, releasing the probes. When released, the probes would penetrate up to about 1 meter (or 3 feet) into the soil.



The dusty or sandy soil may be dry, or it may contain ice. If the soil in the top meter were ice-rich, the probe would have detected the ice in three ways:

- by measuring how fast the probe decelerates. Ice would make soil harder, causing the probes to slow down more quickly than they would in ice-free soil.
- by collecting a soil sample and testing it for water.
- by measuring how quickly the probes cool off after impact.

This activity will focus on how ice in the soil would have affected the temperature of the probe after impact. Initially, the probe would be much warmer than the cold Martian soil. Gradually, however, the probe would lose its heat to its surroundings and would cool down. Thermometers will take the place of the Mars Microprobes.

YOU WILL NEED:

- 2 thermistors connected to either a computer or hand-held display, or 2 scientific classroom thermometers with a temperature range of at least –10 to 50 C*
- 1 or 2 10-oz clear plastic cups*
- 2 1000-ml beakers or 1 1000-ml beaker and 1 600-ml beaker*
- 1 400-ml beaker*
- 1 hot plate*
- 2 straws with a slightly larger diameter than the thermometers*
- ice
- cold tap water
- hot tap water
- clean sand to fill each plastic cup
- access to a freezer the night before the activity
- wax paper
- transparent tape
- watch or clock with a second hand, or stop watch
- spoon (optional)
- masking tape (optional)
- permanent markers to label containers (optional)
- a cooler to transport the frozen materials (optional)
- student access to computer spreadsheet/graphing program or graph paper
- two colors of colored pencils or pens (optional)
- petroleum jelly (optional)

* You will need these supplies for each group of students doing the activity

Break into groups of 2 or 3 students.

Preparation the day before:

1. Wet half the sand, either in a tray or another container.
2. Wrap the end of each straw in wax paper, and cover seams with transparent tape. This will help prevent any excess water in the wet sand from filling the straw. A thin layer of petroleum jelly can be added to the outside of the wax paper to improve the thermal contact between sand and straw, and may help make the wax paper more water resistant.
3. Mark a line 3 cm from the top of each plastic cup for the fill line.
4. While holding the straw, fill one plastic cup with dry sand, up to the fill line. One person can do this, but it will be easier if one person holds the straw and another fills the cup with sand.
5. Once again, while holding the straw, fill the second cup with wet sand. Using a spoon may help. You may need to push the moist sand down with your fingers or a spoon to get it to fill the cup properly. Filling the cup with dry sand and then adding water may increase the likelihood of the straw filling with water as well.
6. Let go of the straws. They should remain upright on their own after the cups have been filled.
7. Using masking tape and markers, label each cup with your name or the name of your group.
8. You may need to cover the cups of wet sand with plastic wrap to keep them from drying out, especially if they will be frozen more than a day or will not go into the freezer right away.
9. Place the cups in a freezer for a few hours or overnight. Be careful not to tip the cups or allow the straws to shift.

The day of the activity:

1. Remove the cups of sand from the freezer just before starting the activity. The water in the sand should be frozen. If you need to remove them more than several minutes before the activity will begin, consider keeping them in a cooler. If you do use a cooler, make sure that any water from melting ice doesn't enter the cups.
2. Add the ice and water mixture to the 600- or 1000-ml beaker to make an ice water bath for one sample.

Experiment Part 1:

1. Make a 3-column table. Label the first column "Time," the second column "Dry sand temperature," and the third column "Wet sand temperature."
2. Place one sample (either wet or dry) into the ice water bath.
3. Fill the 400-ml beaker with water and place on the hot plate. Heat the water to about 40 C. Place one thermistor or thermometer into the heated water. Wait a few minutes for the thermistor or thermometer to reach the temperature of the water. Record the thermistor or thermometer reading as the starting temperature. If you will be doing Part 2 the same day, do not discard the heated water.
4. Place the thermistor or thermometer into the straw in the sample.
5. Record the temperature every 15 seconds for about 5 minutes. One person can read the temperature while another records it.
6. If you used a dry sand sample, exchange data with the group that tested a wet sand sample, and vice versa. Or, repeat the experiment with the other sample. Everyone should end up with two columns of data in their data tables, one for dry sand, and one for wet sand.
7. Test the hardness of the two samples with your fingers. This is another way the probes will look for water ice. The icy sand will be much harder than the dry sand. On Mars, if ground ice is present, the probes will slow down more quickly, and will not go as deep in icy soil as they will in ice-free soil.

Experiment Part 2 (for high school students, immediately following Part 1):

The cooled thermistor or thermometer will be in equilibrium with the cold sample, an ideal starting place for Part 2. Do not remove the thermistor or thermometer from the cold sample. This experiment mimics the sample heating experiment on the microprobes, wherein a tiny soil sample is heated and its rising temperature recorded at regular intervals to see if there is a slowdown during a period of phase change from ice to liquid water.

1. Set up a second water bath in a 1000-ml beaker using the water heated to 40 C. Use a different thermistor or thermometer to measure the temperature of the water.
2. Set up the computer to record temperature data every minute for 15 to 20 minutes.
3. Remove the sample from the ice bath with the thermistor or thermometer still in the straw, and carefully place the plastic cup in the hot water bath. (This may take two students.) Then begin taking data.
4. If you used a dry sand sample, exchange data with

the group that tested a wet sand sample, and vice versa. Everyone should end up with two columns of data in their data tables, one for dry sand, and one for wet sand.

5. If you have another laboratory period available, repeat Parts 1 and 2 with the other type of sample.

Graphing the data for Part 1:

Plot the data for each of the probes on the computer or the same piece of paper, preferably using a different color for each probe. Time should be plotted on the horizontal axis and temperature on the vertical axis. Compare the results from the class. Did one sample consistently cool the thermometer faster than the other?

Graphing the data for Part2:

Prepare a second graph with the data for both the dry and wet samples. If a computer graphing program is used, consider entering the data from each group of students into separate columns. Produce a graph of the data from the entire class for the wet sand and another graph for the dry sand. How did the measurements taken by different groups of students compare with one another? Discuss likely reasons for any differences.

Discussion:

Part 1: Why did the sample with the ice make the thermometer cool down faster?

The icy sand conducts (moves) heat away from the thermometer better than the dry sand. The dry sand has pockets of air around each of the tiny grains. These pockets of air, called pore spaces, act as insulation, and make it harder for the heat to be passed from one part of the container to another. Air spaces are often used as insulation in buildings. Double paned windows have a sheet of glass on either side of a pocket of air. Air space is also used in walls, and insulation usually has a high fraction of pore space.

When water is added and is frozen into the sand, ice fills the pore spaces. The combined material is less insulating and can conduct heat away from the thermometer and into the sand more efficiently. On Mars, dry soil will be even more insulating than dry soil here on Earth. The air in the pores does transport heat in the soil, even if not very efficiently. The denser the air, the better it is at moving heat. On Mars, the air is much thinner than here on Earth, and therefore will be even less efficient at conducting heat.

Part 2: How are the data for the dry and wet samples different? How could this difference be used to detect the presence of water?

In the wet sample, when the temperature reaches 0 C, the heat from the water will go into melting the ice before the sample will begin to rise in temperature. The sample temperature will also not rise as high as will the dry sand, partly because of the energy going into the phase change, but also because of the increased heat capacity of the water.

If this activity had taken place on Mars, would there have been any differences in the observations? Why or why not?

If the Mars Microprobe Mission *did not* find ice in the soil of Mars, would that mean that permafrost doesn't exist on Mars?

No. The probes from the Mars Microprobe Mission were to sample only one area on Mars and would tell us only about the ground near the surface.

What other methods could be used to search for ground ice on Mars? How could those methods be used in designing a spacecraft?

Deep Space 2 Lessons Learned

Cutaway view of test microprobe after it was fired into hard, frozen ground by an air gun.

Although the microprobes were not able to give us the answer to our Martian ice question, designing and developing the probes taught space engineers valuable lessons about building rugged, miniaturized surface penetrators for future planetary exploration. Several designs were tried before a workable one was found. The probes' design was tested extensively by dropping them from an airplane and firing them into the ground with great force using a giant air gun.

Unfortunately, we will probably never know what went wrong on Mars. If we did, we could learn even more from the mission, despite our unanswered science questions.