On the Surface

Space Crisis! The crew of the International Space Station was forced to abandon an important spacewalk mission when the spacesuit of one of the two astronauts involved began to overheat. The malfunction occurred in a new spacesuit introduced by NASA just last week in response to demands for a variety in space attire. Officials are puzzled because the cooling system inside the suit appeared to be operating efficiently.

Astronauts depend on their spacesuits to offset the harsh temperatures encountered in outer space. Heating and cooling systems inside the suits are devised to moderate the wide range of temperatures. However, the length of time the suit can be used before recharging is limited since those systems operate on electricity. Can the color of the suit affect the efficiency of the cooling or heating system?

Investigation

You have been asked by NASA to investigate the cause of the malfunctioning spacesuit. Initial reports indicate that there were virtually no changes in the internal operating systems of the suit. Likewise, the insulating layers were not modified in the faulty suit. Designers simply changed the color and texture of the outer layer of the garment. Could this slight change in design really have an impact on heat absorption?

Objectives

In this experiment, you will:

- Use a Temperature Probe to measure the temperature change of various covering materials
- Use the ProScope Digital USB Microscope to examine materials
- Develop an understanding of the effect different colors and reflective surfaces have on radiant heat absorption
- Demonstrate the effect of light absorption on heat
- Report your findings to NASA by creating a lab report using iPhoto or iMovie software

Materials

- Macintosh computer with Mac OS X
- iMovie or iPhoto software
- AppleWorks software
- Bodelin ProScope Digital USB Microscope
- Bodelin USB Shot software
- Bodelin 200X lens
- Vernier Go! Link interface
- Vernier Temperature Probe
- Vernier Logger Lite software
- White and black construction paper (or fabric)
- Aluminum foil
- Three shoeboxes (the same size)
- Tape or glue
- Lamp with 100-watt bulb
- Scissors

Pre-lab activity

In your science journal, write a hypothesis that explains why the spacesuit is overheating. Explain your reasoning.

Procedure

1. Obtain and wear goggles.
2. Place the lids on the shoeboxes, then cover one box with the white material, one with the black material, and one with aluminum foil.
3. Set up the ProScope to examine each of the box-covering materials.
   - **a** Connect the ProScope to a USB port on the computer.
   - **b** Open the USB Shot application.
     You should now see an image on your computer screen.
   - **c** For each sample, touch the tip of the ProScope with the 200X lens to the material to view an image.
   - **d** Press the button on the ProScope to snap a still image.
4. Label the image with the name of the material, then file it in a folder you create. The image can be found in the SNAP folder, which is located in your Applications folder. Rename the image with the name of the material and drag it into a new folder you have created for this experiment.

5 Insert the image into a data table like the one shown in "Processing the data," and write a description of what you see.

6 Cut a hole into the side of each shoebox just large enough so that you can slide the Vernier Temperature Probe inside. The probe should be completely inside the box.

7 Repeat steps 3 through 6 with each covered box (aluminum foil, white, and black construction paper).

8 Place the Temperature Probe inside one of the boxes, and then position the box under a 100-watt lamp. Situate the light source so that it is directly over and approximately two inches above the box.

9 Connect the Go! Link interface to the computer and the Temperature Probe to the Go! Link. Open the Logger Lite application.

The computer recognizes the Temperature Probe. The Logger Lite application defaults to degrees Celsius.

10 Choose Data Collection from the Experiment menu.

11 In the Collection Setup dialog, type "600" for the length of the experiment in seconds, and type "10" for the number of seconds per sample. Click Done.

12 Turn on the lamp and begin collecting data by clicking the Collect button.

The Logger Lite program collects temperature data for a period of ten minutes (600 seconds).

13 When the data collection is done, click the Stats button and record the minimum and maximum temperatures in your data table.

14 Calculate the change in temperature by subtracting the beginning temperature from the ending temperature.

15 Repeat the procedure using the boxes covered with white and black construction paper.

16 Use your data to construct a bar graph to visually organize the data.

17 Use iPhoto to create a storybook or iMovie to produce a movie displaying your experiment and conclusions.

Processing the data

Use the changes in temperature you calculated to construct a bar graph that visually represents your data, then create a digital lab report summarizing your experience using iPhoto or iMovie. Use your ProScope images and your data to illustrate your lab report. The recorded data should guide your work.

	Aluminum Foil	White Paper	Black Paper
Beginning Temperature			
Ending Temperature			
Temperature Change			
ProScope Image			
Description			

Analyzing your data

1 Which of the materials absorbed the most light? (This will be demonstrated by the biggest increase in temperature.)

2 Which of the materials reflected the most light? How can you tell?

3 What is the relationship between light and heat?

4 Using the ProScope images and the data collected from the Temperature Probe, what factors do you think affect reflectivity and heat absorption?

Teacher Information

According to the law of reflection, the angle of incidence is equal to the angle of reflection. That is, the angle at which light strikes a surface will be the same as the angle it reflects, or bounces off, that surface. If the reflecting surface is smooth (like a mirror), the light will bounce off all points of the surface at the same angle and produce a regular reflection. If the surface is rough (like a piece of paper), the light will strike the surface and bounce off at a number of angles. This will produce what is known as a diffuse reflection.

Materials

You may substitute a heat lamp for the lamp with a 100-watt bulb. Take the proper precautions if your students will be using a heat lamp.

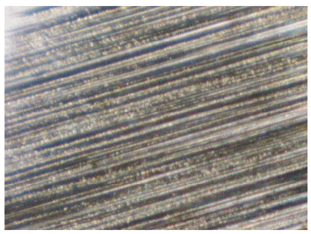
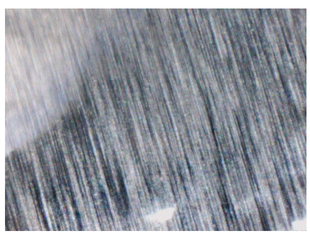
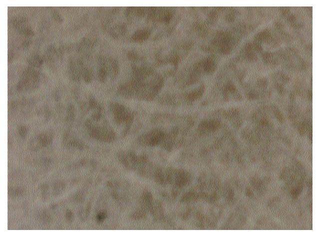
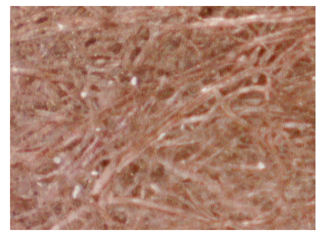
You may substitute cardboard paper towel tubes or toilet paper tubes for the shoeboxes.

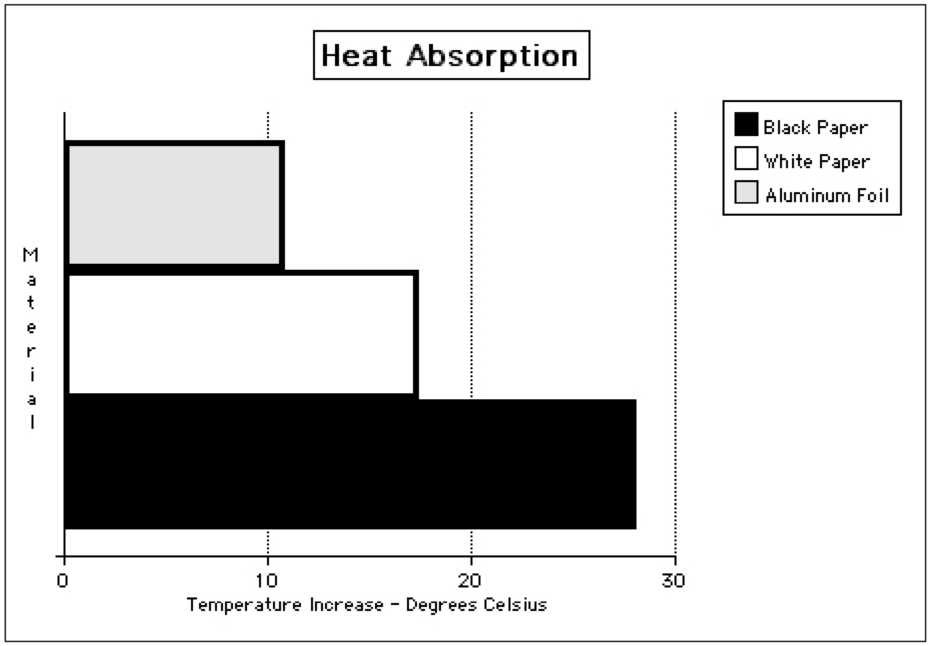
Hypothesis

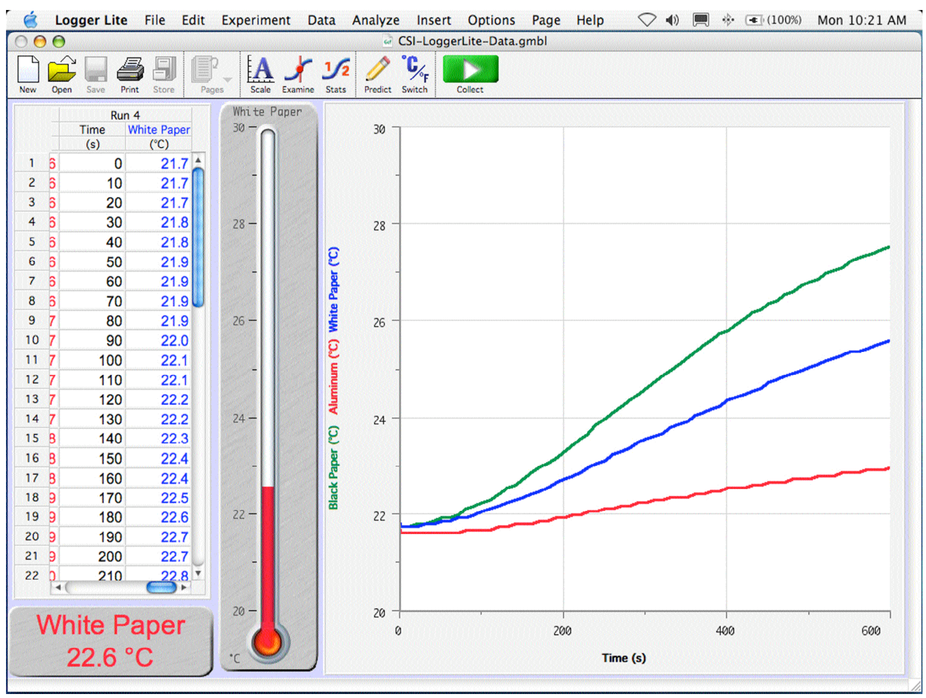
To reinforce the concept of regular versus diffuse reflection, have students look for their reflection in the aluminum foil and in each of the colors of construction paper. They should be able to see themselves in the foil, but not in the paper. This is because the regular angle of reflection off the foil bounces back to their eyes, whereas not all the angles of reflection off the paper are being directed toward the eye.

When light energy is transferred to particles of matter, the light is said to be absorbed. Black absorbs all colors of light, while white reflects all colors of light. Light energy is transformed into thermal energy in this experiment, causing the increase in temperature. Each material absorbs and reflects a different amount of energy. Students should realize that the smoothness of the aluminum foil caused much of the light to be reflected. They should also recognize that the white construction paper reflected more light than the black construction paper. Darker objects absorb more light, and therefore more heat.

Sample results

	Aluminum Foil	**White Paper**	**Black Paper**
Beginning Temperature	23.68	25.19	26.30
Ending Temperature	34.45	42.53	54.32
Temperature Change	10.77	17.34	28.02
ProScope Image	 	 	 
Description of Image	The aluminum foil has very straight parallel lines. There seems to be a pattern of colors from white to black not apparent to the naked eye.	The lines of the white construction paper are like a tangled ball of yarn. There appear to be spaces between the fibers.	The fibers of the black construction paper appear tangled with spaces in between like the white paper. The fibers, however, are much darker, and composed of a number of pigments.


Heat Absorption
Black Paper
White Paper
Aluminum Foil
Material
0
10
20
30
Temperature Increase - Degrees Celsius


Logger Lite File Edit Experiment Data Analyze Insert Options Page Help
Mon 10:21 AM
CSI-LoggerLite-Data.gmbl
New Open Save Print Store Pages Scale Examine Stats Predict Switch Collect
Run 4
Time (s)
White Paper (°C)
White Paper
22.6 °C
Black Paper (°C) Aluminum (°C) White Paper (°C)
Time (s)

Answers to analyzing your data questions

1 The black construction paper absorbed the most light.

2 The aluminum foil reflected the most light. This is evident because the temperature of the foil increased the least. Since light is energy, absorption of light causes temperature to increase.

3 Light and heat are both forms of energy. Light is converted into thermal (heat) energy in this experiment.

4 The two factors that affected heat absorption in this experiment were color and smoothness.

Extensions

1 Students can try this experiment with different colors.

2 What differences would you see if you used different colored light bulbs instead of different types of materials? Have students use just one type of paper, such as white construction paper, and experiment by shining in turn a red, green, white, and black light bulb on it.

3 What would happen if the boxes were subjected to extreme cold? Students can place the covered shoeboxes in an ice-filled cooler, a freezer, or on a block of dry ice.

4 Students can create an iMovie project tracing the history of the spacesuit or explaining how spacesuits work.

5 Ask students to create a spacesuit appropriate for use on Mars. Have them use iMovie to describe their design.

National Science Standards

This experiment provides direct alignment to national standards by allowing students to observe and measure light and heat absorbance. The design of the experiment also emphasizes alignment with measurement, inquiry, and investigative standards by having students use technology to practice and gain insight into these skills.

National Science Standards

Unifying Concepts and Processes:

1 Evidence, models, and explanation.

2 Change, constancy, and measurement.

Science as Inquiry

Content Standard A

As a result of activities, students should develop

1 Abilities necessary to do scientific inquiry.

2 Understandings about scientific inquiry.

National Content Standards

Level 5-8, Physical Science Standards

Content Standard B. Transfer of energy

Energy is transferred in many ways.

Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection).

Special thanks

This lesson was written by Linda Trawick, Science Coordinator and National Board Certified Teacher, Smitha Middle School, Marietta, GA, and edited by Jack Randall, Vernier Software & Technology.