LESSON 4

GETTING HOTTER

Purpose: Students will discover the existence of non-visible light, infrared, outside of the visible light spectrum. Students will learn how infrared is used in science. Students will also develop experimental techniques useful for further exploration of the light spectrum.

Benchmarks for Science Literacy:

- Scientists differ greatly in what phenomena they study and how they go about their work. Although there is no fixed set of steps that all scientists follow, scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence. 1B/1 (6-8)
- **Sometimes scientists can control conditions in order to focus on the effect of a single variable.** When that is not possible for practical or ethical reasons, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns. 1B/3 (9-12)
- **Increasingly sophisticated technology is used to learn about the universe.** Visual, radio, and x-ray telescopes collect information from across the entire spectrum of electromagnetic waves; computers handle an avalanche of data and increasingly complicated computations to interpret them; space probes send back data and materials from the remote parts of the solar system; and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed. 4A/3(9-12)
- Accelerating electric charges produce electromagnetic waves around them. **A great variety of radiations are electromagnetic waves:** radio waves, microwaves, **radiant heat**, visible light, ultraviolet radiation, x rays, and gamma rays. These wavelengths vary from radio waves, the longest, to gamma rays, the shortest. In empty space, all electromagnetic waves move at the same speed—the "speed of light." 4F/3 (9-12)

National Science Education Standards:

Grades 5-8

Physical Science – Transfer of Energy

- The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the

earth. **The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared**, and ultraviolet radiation.

History and Nature of Science – Nature of Science

- Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.

History and Nature of Science – History of Science

- Many individuals have contributed to the traditions of science. Studying some of these individuals provides further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society.

Gradres 9-12

Science as Inquiry – Abilities Necessary to do Scientific Inquiry

- COMMUNICATE AND DEFEND A SCIENTIFIC ARGUMENT. **Students in school science programs should develop the abilities associated with accurate and effective communication. These include writing and following procedures, expressing concepts, reviewing information, summarizing data, using language appropriately, developing diagrams and charts, explaining statistical analysis, speaking clearly and logically, constructing a reasoned argument, and responding appropriately to critical comments.**

Physical Science- Interactions of Energy and Matter

- Electromagnetic waves result when a charged object is accelerated or decelerated. **Electromagnetic waves include** radio waves (the longest wavelength), microwaves, **infrared radiation** (radiant heat), **visible light**, ultraviolet radiation, x-rays, and gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength.

Background:

Infrared light is a range of wavelengths of the electromagnetic spectrum that is adjacent to red visible light. While the wavelengths of visible light range from about 390 nm (violet) to about 770 nm (red), the

infrared range is from 770 nm to about 1,000,000 nm. Sir William Herschel discovered the existence of infrared light in 1800 when he was attempting to discover why different colored telescope filters passed more heat than others. Herschel separated visible light with a prism and placed the bulbs of thermometers in different parts of the visible spectrum. He found that the hottest temperatures are recorded for the thermometer just beyond the red band where there was no visible light. He concluded that there was light invisible to our eyes beyond red. (He further tested this invisible light and found that it was reflected, refracted, absorbed, and transmitted like all visible light.) However, it may be difficult for your students to conclude that something is there that they can't see.

Infrared light is not visible to humans. You and your students cannot see or touch it. This presents difficulties for some students. Even visible light presents difficulties for many students. "Few students hold a conception of light as a physical effect existing apart from its source and effects." (Arons, p226) The only evidence for infrared light that students will record is the higher temperature measured by the thermometer that is placed just adjacent to the red part of the spectrum. According to their previous experience, this may not be sufficient evidence. They may dismiss the results as experimental error. Therefore, it is important that students be aware that all of the groups recorded the same results.

Note: There is an excellent explanation of an experiment similar to the one described here on the web page called *An Example of the Herschel Experiment* http://sirtf.caltech.edu/Education/Herschel/backyard.html . The web page *Herschel and His Discovery of Infrared* gives an historical background to the problem http://sirtf.caltech.edu/Education/Herschel/herschel_bio.html . Also visit *Herschel Infrared Experiment* for a procedure with drawings of the equipment http://sirtf.caltech.edu/Education/Herschel/experiment.html. However, do not provide your students with a history lesson about Herschel before the investigation. You want your students to gather the data and attempt to interpret it. If you mention Herschel, they may research Herschel instead of thinking about the data.

Overview of Student Assignments for Getting Hotter?

1. **How Are Parts of the Spectrum Different?** is a journal assignment to engage your students in thinking about characteristics of the spectrum. Their ideas will be used in Lesson 6 to develop an inquiry of their choosing.

1. **Laboratory Investigation** is a formal lab to determine whether different colors in the light spectrum heat objects differently.
1. **Data Sheet** is used to record data.
1. **Conclusions** requires the student to write a thoughtful, short essay that answers the central question of the lab.
1. **Prediction Reflection** will allow the students to reflect upon the prediction they made at the beginning of the **Laboratory Investigation**.
1. **Reading Assignment** "Seeing Our World in a Different Light" at http://sirtf.caltech.edu/Education/IRapp/intro.html.

Materials per group:

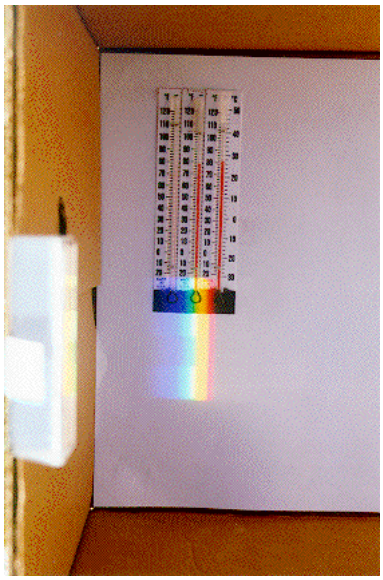
- Equilateral **glass** prism
- Prism holder (optional)
- 3 alcohol thermometers
- Tape
- Cardboard box (a photocopier paper box works very well)
- Black spray paint (black marker will work)
- White paper for bottom of box
- Scissors
- **Getting Hotter Procedure** sheets for each student
- 3 **Getting Hotter Data** Sheets per group
- **Getting Hotter Conclusion** sheets for each student
- **Prediction Reflection** for each student (Appendix)

Preparation and Procedures:

1. Assign the journal assignment **How Are Parts of the Spectrum Different?** It is recommended that you assign the journal as a homework assignment. However, you may use part of a class period to have your students reflect upon and answer the questions. You know your students best, and you know best which format will achieve the desired goals for this assignment. Do not give your students any information about the exploration, **Getting Hotter**, yet.
1. When the students have completed the journal assignment, have them share their ideas about further investigations in a full class discussion. It is possible that a student will suggest investigating the temperature of different parts of the visible spectrum. However, if no one does, simply state at the end of the discussion that in 1800 a scientist wanted to

know if different parts of the visible spectrum would heat objects differently. Do **not** tell students that the scientist was Sir William Herschel. You want them to evaluate evidence, not research Herschel and find out what he discovered. There is a reading activity about Herschel at the end of this unit.

1. Remind your students that they will be designing their own investigations from these questions. It is important for them to know that their thinking is valued and will be incorporated into class work. Tell them that the exploration, **Getting Hotter**, will allow them to develop a better understanding of light and will also serve as a model for their own investigation later.
1. Blacken the bulbs of each thermometer with paint or marker before the exploration. Spray paint works best. The blackened bulbs will absorb heat and produce better results. After the paint has dried, tape three thermometers together so that the temperature scales line up. There should be about a half of a centimeter of space separating the bulbs
1. If you do not have prism holders, cut a notch out of the top edge of the box on one of the narrow sides. The notch should hold the prism tightly and still allow it to rotate slightly. It is best to do this experiment outside on grass on a sunny day. Clouds or haze will interfere with your results. The grass will protect the prism in case it is dropped. Also, remind students that the Earth is turning so the spectrum will shift while they are recording temperatures. They must shift the thermometers to keep them in the same place in the spectrum.



6. Have the students post their results on the board or an overhead so that all class data is available to everyone. When all results have been posted, conduct a brief class discussion of the data to focus on the fact that every group (should have) recorded highest temperatures in the region beyond red. There is no reason to tell them the answer. There is still much for them to think about. But help them to realize that many groups recorded the result.
7. Assign the **Conclusion**. Give them time (one of two days) to think and to write a carefully constructed essay
8. After the students have submitted their conclusions, assign the reading *Herschel Discovers Infrared Light* found at http://sirtf.caltech.edu/Education/Herschel/herschel_bio.html. This can be a computer assignment or you can print the article from the web site.
9. Assign a **Prediction Reflection**. The students should reflect upon the original prediction they made at the beginning of the experiment.
10. Assign reading, "Seeing Our World in a Different Light" at http://sirtf.caltech.edu/Education/IRapp/intro.html.
11. Optional - assign a 1-2 page paper in which students explain the benefits of the use of IR in one of 18 areas listed at the bottom of the first page of the above web site. They will need to research the area in greater depth. If you can assign this as a computer assignment, students can insert images from the web site. If you have sufficient time, students could prepare a PowerPoint or Webpage presentation to be presented to the class.