Electromagnetic Radiation Part 1

STARFINDER
PROGRAM 23

Instructional Objectives

After viewing the program and participating in the accompanying activities, the student will be able to:

1. describe visible light and radio waves as the forms of electromagnetic radiation which fully permeate earth's atmosphere,
2. identify the interaction of electric and magnetic fields as means of electromagnetic transmission, and
3. explain how people are using infrared radiation to learn about earth and space.

Synopsis

Program 23 begins with "HST Data Stream." Some of the latest information received from the Hubble Space Telescope is presented by Eric Chaisson. Dr. Chaisson shows us how the HST "acquires" or takes a photograph of Mars.

"Science Links" begins with a visit to a Gaithersburg, Maryland science classroom in which students are monitoring weather phenomena by viewing infrared satellite images of earth. The infrared is presented as one form of the full electromagnetic spectrum.

Students are shown two experiments that led to the discovery that invisible forms of energy extend beyond the boundaries of visible light. William Herschel's experiment, in which he passed sunlight through a prism to measure the temperature of the different bands of colored light, led to a surprise discovery that some form of radiation, the infrared, existed just outside the red band of light. In an analogous experiment, Johann Ritter discovered a band of energy, the ultraviolet, just beyond the violet.

The program combines the notions presented in previous programs that electromagnetic energy travels in waves, and that there is a reciprocal relationship between magnetism and electricity. Electromagnetic waves are presented as an interaction of perpendicular wavelengths of electric and magnetic fields.

Satellite and future Hubble Space Telescope detection of the infrared completes the show.

In "The People Behind the HST," we meet Colonel Charles Bolden. Col. Bolden was the pilot of the space shuttle mission that placed the Hubble Space Telescope in orbit.

Vocabulary

Electromagnetic Radiation - A form of energy that travels at the speed of light.

Electromagnetic Spectrum - The full range of the various types of electromagnetic radiation which include radio, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays.

Gamma Rays - The form of electromagnetic energy with the highest frequency and smallest known wavelengths.

William Herschel (1738–1822) - German born astronomer who discovered the planet Uranus. His measurements of temperatures of different colors of light led to the discovery of the infrared.

Infrared - The form of electromagnetic radiation with slightly longer wavelengths and slightly smaller frequencies than those of visible light.

IRAS - Infrared Astronomical Satellite - Launched in 1983, the first infrared astronomy satellite, designed to map the stars in the longer infrared wavelengths.

Microwaves - The radio waves with the shortest lengths.

Radio Waves - The form of electromagnetic radiation with the longest wavelengths and smallest frequencies.

Johann Ritter (1776–1810) - German physicist whose experiments led to the discovery of the ultraviolet.

Silver Chloride - Compound containing silver which darkens when exposed to ultraviolet light.

Slue - An adjustment in the pointing of the telescope.

Ultraviolet - The form of electromagnetic radiation with slightly greater frequencies and slightly shorter wavelengths than visible light.

Visible Light - The narrow range of the electromagnetic spectrum which is visible to the human eye.

WF/PC - The acronym for Wide Field Planetary Camera. Pronounced "wifpic.".

X-rays - Electromagnetic radiation which has wavelengths between those of the ultraviolet and gamma rays.

Previewing

Review the basic properties of electric and magnetic fields.

Review the "HST Data Stream" from Program 19. In this program, Eric Chaisson shares a poster that illustrates the electromagnetic spectrum.

Review Program 22, Magnetic Fields. Ask students to recount an experiment they saw in the program or carried out in the classroom which demonstrated the relationship between magnetism and electricity.

Preview properties of light waves—wave lengths, crest, speed of light, and the spectral colors of visible light. Remind students of the wave particle duality which was presented in Program 15.

Remind students that there are other types of telescopes besides optical telescopes. Display radio images, optical images, and x-ray images of the universe.

Bring an infrared weather satellite image to class. Use this to open a discussion about invisible forms of light waves.

Postviewing

Have students describe the interaction of magnetic fields and electric fields in electromagnetic radiation. Have them diagram the perpendicular interaction of the waves.

Emphasize the vast range of electromagnetic wavelengths. The longest waves can measure 1,000 meters. The shortest ones are less than one billionth of a meter. This is referred to as a nanometer. Point out that even though the frequencies also vary, all electromagnetic radiation travels at the same speed—186,000 miles per second.

Have students diagram the range of the electromagnetic spectrum, and distinguish between the types of radiation passing through the earth's atmosphere and those that are blocked by it. Discuss how the depletion of the ozone layer around the poles is allowing more ultraviolet light to enter our atmosphere.

Discuss the many ways in which the infrared is used in science and technology. Describe several discoveries that have been made through the study of infrared radiation in space. Discuss Landsat Imaging Systems, in which telescopes are aimed back at earth. Infrared imaging is also used closer to earth, often saving lives by detecting sources of heat during search and rescue missions. In darkness or overgrown terrain, the bodies provide a heat source detectable to FLIR, or Forward Looking Infrared systems. Also useful in energy conservation, infrared imaging can detect heat loss from homes and buildings. A good source of information is White's *The Invisible World of the Infrared.*

Encourage students to read the biographies of the scientists highlighted in this program. William Herschel began his adult life as a musician, but became a noted astronomer. Students might compare this to the interests of Skip Westhpal, a modern day musician turned astronomical photographer. Skip was featured in "The People Behind the HST" in Program 19.

In "Science Links," students are reminded that they can feel the heat emanating from a stove burner before it actually glows red. Have students think about other objects that give off heat without appearing to glow. Make sure students understand that the infrared rays themselves are not hot.

Place a floating object, such as a cork, in a pan of water. Have students observe the movement of the cork as waves are created.

Have students compare and contrast the variety of substances that different forms of electromagnetic radiation are able to penetrate. Use pieces of plexiglass, translucent paper, and cardboard as examples of substances visible light can and cannot penetrate. Bring an X-ray to class for a discussion of what substances X-rays can penetrate. Use the fact that we can hear a radio inside a house but need antennae to receive radio signals inside a car. Most students will be familiar with popping popcorn in a microwave oven. Have them take note of the temperature of the popcorn and the temperature of the container. The microwaves pass through the paper container, but the popcorn absorbs the microwave energy. Extend the discussion to include earth's atmosphere blocking some forms of electromagnetic radiation and not others.

Active Involvement

For each type of electromagnetic radiation, have students report on a discovery that has been made from space. For example, radio astronomy—pulsars.

Art historians X-ray works of art to discover old paintings that may be hidden under a newer paint layer. X-ray telescopes allow astronomers to see objects that are too faint for optical telescopes, or are obstructed by clouds of gas and dust. Various forms of medical X-rays provide clues to what is going on in the human body. Ask students to find other ways that X-rays are used as detective tools.

Discuss uses of radio waves as radar. The use of radar allows people to determine the distance of an object by measuring the amount of time it takes for a radio signal to reach the object and return to the radar. Compare and contrast radar with laser range finders. Have students diagram how each works, and then compare and contrast. Light waves vibrate in all directions. A polarizing substance serves to filter out all but the waves vibrating along one plane. You can demonstrate this to the class with a pair of Polaroid sunglasses. Have a student look into a sunny sky, at a 90° angle from the sun. Direct him or her to hold a Polaroid lens to one eye and note the difference in light. If the student rotates the lens, the brightness will change. Using a second pair of Polaroid sunglasses, have a student look through two lenses at once and note the degree of brightness passing through the lenses. If one pair is turned 90° to the first, most of the light will be blocked. This is because the polarizing filter of the second pair cancels out the remaining plane of light waves.

One way to demonstrate that larger amounts of energy are transmitted by shorter wavelengths is through the waves produced by a rope. Tie a rope to door knob or chair. Have a student take the other end and begin moving his or her hand up and down in a regular pattern, creating a series of waves. Ask the student to move faster and have the other students compare the length of the waves to the speed of the movement.

A "Dynamic Human Model" (printed courtesy of Jeanne Bishop, Westlake Schools, Westlake, Ohio) can help demonstrate to students the different wavelengths of the electromagnetic spectrum. Mark three parallel lines on the ground or floor. The lines represent paths of red, yellow, and blue light. Place sticky dots of different colors on the lines. The red light line has red dots, the yellow light line has yellow dots, and the blue light line has blue dots. Place the red dots about 100 cm apart, the yellow dots about 80 cm apart, and the blue dots about 60 cm apart. One student walks along each line simulating a traveling transverse light wave. All students begin by crouching on the first dot of a line. On reaching the next dot in a line, the student is to be fully upright. On each subsequent dot the student is crouched or upright, alternately. All students should progress down the light lines at the same rates, illustrating that all light waves travel at the same velocity in the same medium. To accomplish this, students moving on the lines with closer-spaced dots will have to go up and down faster. This demonstrates that yellow and blue light have more energy than red light, and have higher frequencies. Waves in non-visible sections of the electromagnetic spectrum can also be modeled. Point out to students that the waves actually travel much more rapidly than they can move, and unless polarized, vibration is in many planes centered along a line.

The ASTRO observatory, a space shuttle based observatory for ultraviolet astronomy, was launched December 2, 1990. The ultraviolet telescopes aboard the space shuttle were the Hopkins Ultraviolet Telescope (HUT), the Ultraviolet Imaging Telescope (UIT), and the Wisconsin Ultraviolet Photopolarimetry Experiment (WUPPE). Have students find out as much as they can about the ASTRO mission. Use this as an example of co-observational science, in which the information gleaned from multiple observations is combined to form more complete information.

If students did not measure the temperatures of various colors of light as a post viewing activity to Program 17, "The Hubble Instruments", have them complete it after this program. It demonstrates William Herschel's experiment that led to the discovery of the infrared.

Invite a guest speaker to the classroom to discuss one of the many fields that use lasers as tools. You may wish to invite a physician who performs laser surgery.

Bibliography

For high school readers.

Conell, J. and P. Gorenstein. *Astronomy from Space*. Boston: MIT Press, 1983.

Rublowsky, J. *Light*. New York: Basic Books, 1964.

Tucker, W. and K. *The Cosmic Inquirers*. Cambridge: Harvard University Press, 1986.

White, Jack R. *The Invisible World of the Infrared*. New York: Dodd, Mead, and Co., 1984.

For middle school readers:

Branley, Franklyn M. *The Electromagnetic Spectrum*. New York: Thomas Y. Crowell, 1979.

Kohn, Bernice. *Light You Cannot See*. Englewood Cliffs: Prentice-Hall, Inc., 1965.

Lewis, Bruce. *What is a Laser?* New York: Dodd, Mead & Co., 1979.

Vogt, Gregory. *Electricity and Magnetism*. New York: Franklin Watts, 1985.

See for Yourself: Experiments/Projects

Discovering the Ultraviolet

(adapted from ASTRO-1 Teacher's Guide, a product of NASA)

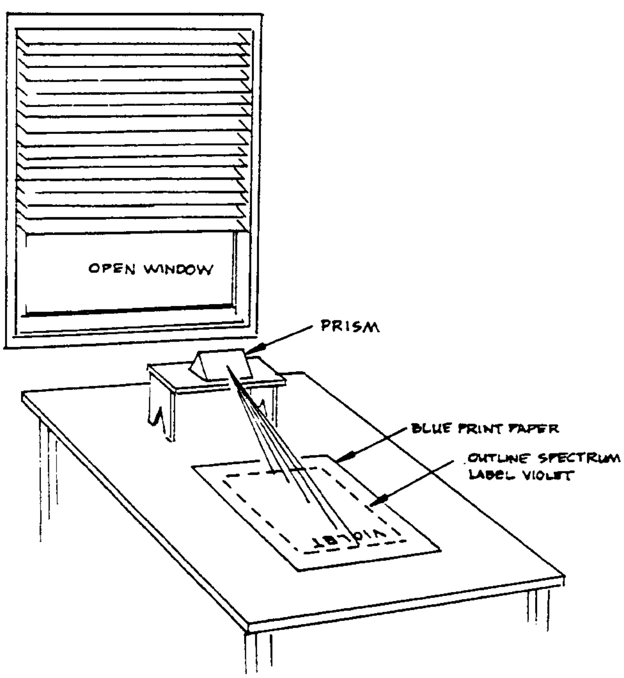
To demonstrate the existence of ultraviolet radiation, you can duplicate Johann Ritter's experiment that was demonstrated in this program. In 1801, Johann Ritter performed an experiment using paper treated with silver chloride, a chemical which darkens in the presence of light. He discovered that the paper reached its darkest color at its fastest rate when exposed to ultraviolet light. Because it is undetectable to the human eye, the ultraviolet was previously unknown.

▶ MATERIALS:

- several sheets of blueprint paper
- 1 qt. (about one liter) of household ammonia
- flat pan
- prism
- light source

▶ PROCEDURE:

Using a prism, create a spectrum on a horizontal surface, such as a table. Darken the room as much as possible, so that the only light in the room is that coming through an open window. Use sunlight from an open window, as glass blocks most of the ultraviolet radiation. The prism should be resting on a stable object so that the spectrum does not move.



Work quickly to prevent exposure of the paper to too much light. Cut a piece of blueprint paper about four times larger than the spectrum. Place the blueprint paper (which behaves the same way that Ritter's silver chloride paper did) underneath the spectrum. Quickly outline the area covered by the spectrum with a felt-tip pen. Label the violet end.

Depending on the sensitivity of the paper, different exposure times will be needed. Most exposure times will be fairly brief, however—about 15 to 20 seconds.

Put just enough ammonia in the pan to cover the bottom to a depth of about 0.5 inches (1 cm). In front of an open window, or beneath a vent fan, hold the paper over the pan of ammonia so that the fumes will process the paper. Notice the changes in the area outlined and the area just beyond the violet end. You may have noticed that this area began to change even before processing with the ammonia.

Write a brief description of the results of your experiment. In your description, compare this experiment to the experiment conducted by William Herschel in which he first detected infrared radiation by measuring the temperatures of the different bands of color, and the area just below the red band.

You may also wish to use a silver nitrate solution to detect ultraviolet light. Soak two inch strips of filter paper in a solution of silver nitrate. Place one strip in a protected sunny location outdoors. Place a second strip in a room that is lit with fluorescent lighting. Place a third strip on a spectrum you have created just as you did in the previous experiment. Compare and contrast the colors of the three strips, and state why you think they produced different color intensities.

Investigating Lasers

Lasers are being used in more and more capacities in our world today, but do you know how a laser works? After learning about electromagnetic radiation and light energy, you are ready to discover the world of the laser.

The name LASER is an acronym, a term which is created by combining the first letters of related words. The acronym LASER stands for

L - light
A - amplification by
S - stimulated
E - emission of
R - radiation

1. To better understand lasers, write a definition for each of the words used in the laser acronym.
2. By now, you know that light is one form of electromagnetic radiation that travels in waves. Remove the shade from a small lamp and switch on the light. In which direction(s) is the light leaving the bulb? If you move a piece of paper around in the area surrounding the bulb, you will see the light shining equally in all directions.
3. Imagine what the differences in light would be if all the light waves traveled in one direction, were of exactly the same amplitude and length, and whose waves began at precisely the same point. Lasers use mirrors and a tube to create this effect. Go to the library and research the construction of lasers. Draw and label a diagram of a laser.
4. Lasers are increasingly being used in a wide variety of fields such as medicine, art restoration and cleaning, military defense, photography (holograms), industry, and entertainment. Choose one area of interest and research the many uses of lasers.

Books that may be of assistance:

Eskow, Dennis. *Laser Careers*. New York: Franklin Watts, 1988.

Filson, Brent. *Exploring with Lasers*. New York: Julian Messner, 1984.

Kellenkamp, Larry. *Lasers, the Miracle Light*. New York: William Morrow & Co., 1979.

Stevens, Lawrence. *Laser Basics*. Englewood Cliffs: Prentice Hall, 1985.

Career Profile

Charles F. Bolden Jr. (Colonel, USMC)
NASA Astronaut
Education: B.S. Electrical Science
M.S. Systems Management

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United States Marine Corps Colonel Charles Bolden Jr. speaks very enthusiastically and energetically about what it's like to be in space. "The view from the space shuttle is spectacular," he says. "The shuttle's windows are prime real estate during a flight." Colonel Bolden's favorite time to view the earth is during darkness when he can look down and see lightning all across the cloud tops for hundreds of miles. "It's as if someone were conducting an orchestra with all kinds of lights."

When Charles Bolden graduated from C.A. Johnson High School in Columbia, South Carolina in 1964, being an astronaut was the farthest thing from his mind. Flying seemed inherently dangerous to him. Being a scuba diver held much more appeal. Yet, as soon as he graduated from the United States Naval Academy in 1968, he accepted a commission as a second lieutenant in the U.S. Marine Corps and later went to flight school and became a naval aviator in 1970.

After flying more than 100 sorties into North and South Vietnam and graduating from the U.S. Naval Test Pilot School at Patuxent River, Maryland in 1979, Charles was selected by NASA in 1980 to become an astronaut. In 1981, he qualified for and was given the assignment of pilot on future space shuttle missions. To date, Colonel Bolden has flown two of these missions. His first was a six day flight of the space shuttle Columbia in 1986 to deploy the SATCOM KU satellite and to conduct experiments in astrophysics and materials processing. On his second successful mission, Colonel Bolden was pilot on the crew of the space shuttle Discovery, whose mission was to launch the Hubble Space Telescope on April 24, 1990. Colonel Bolden has logged a total of 267 hours in space.

As an astronaut, Charles' daily routine involves lots of report writing, attendance at meetings, and participating in evaluations of landing and rollout systems for future shuttle use as well as the remote manipulator system (RMS) for future shuttle and space station activities. Occassionally, there are opportunities to fly a supersonic jet, the T-38. Once assigned to a crew and a specific mission, Charles' work asssignments become more directly related to that flight. The object of this training is for the mission activities to become second nature so that nothing will be a surprise from a technical standpoint.

During his 267 hours in space, Charles has had the opportunity to see and do things that most people don't get to do in a lifetime. Charles finds space flight exhilarating. "When you're outside the earth's atmosphere," he says, "the stars are so much more vivid. There are millions of them instead of just a few hundred or the few that you can count at night. We can see the craters and the mountains on the moon a lot better than you can from the earth. It's just a breath-taking experience—a once in a lifetime experience."

Colonel Bolden has received a number of special honors during his career. He is recipient of the Defense Superior Service Medal, Defense Meritorious Service Medal, the Air Medal, the Strike/Flight Medal, the University of Southern California (Ebonics Support Group) Outstanding Alumni Award (1982), the NASA Exceptional Service Medal (1988), and has received several honorary doctoral degrees. Currently, Charles is assigned to command the crew of the 1992 space shuttle Atlantis STS-45 (ATLAS) mission which will be dedicated to studying atmospheric phenomena.

Career Viewpoint

Charles' career goals have changed directions several times on route to becoming an astronaut. Even his current position he considers to be an intermediate goal. Charles feels that his junior and senior high school studies were critical in preparing him for the many career experiences that he has had.

Charles recommends that in order to be flexible and to prepare for whatever career decisions may lie ahead, it's best to take as many math and science courses as possible early in your schooling. He also suggests that you take an interest in science fair projects. The process that you go through to research and develop your selected science project will provide you with some of the basic skills needed for any future career path that you might pursue.

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A production of

MARYLAND STATE DEPARTMENT OF EDUCATION
MARYLAND INSTRUCTIONAL TECHNOLOGY • INTEC

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Major funding provided by

MARTIN MARIETTA

and
U.S. Department of Education

Office of Educational Research and Improvement

Fund for the Improvement and Reform of Schools and Teaching

Dwight D. Eisenhower National Mathematics and Science Program