Unit 4: THE MESSAGE OF LIGHT

Except for meteorites and a few samples of Moon rocks and soil brought back by Apollo astronauts, we have no physical materials from celestial objects in or beyond the Solar System. Yet we have considerable knowledge of these objects, even though they may be up to billions of light years away. One way that astronomers "observe the universe" is through electromagnetic radiation (EMR), commonly referred to as the electromagnetic spectrum. Visible light is only one part of the spectrum that opens up windows to the universe. All parts of the spectrum offer us unique information. Analysis of the spectrum gives astronomers a vast amount of information about stars, including age, mass, composition, temperature, luminosity, and evolutionary history. Chapter 8, "The Nature of Light," discusses the physical properties of electromagnetic radiation. Chapter 9, "The Life of a Star," explains how spectroscopy, the study of electromagnetic radiation, gives us the information we need to determine the evolutionary stage of a star.

CONTENTS FOR UNIT 4

Relationship to National Science Standards and Benchmarks

Unit 4 addresses the knowledge of light, energy properties and transformation, and the Sun's energy, as stated in the *Physical Science* content standard for eighth grade students. The *Physical Science and Earth/Space* content standards for twelfth grade students requires knowledge of nuclear fusion, nucleosynthesis, atomic structure, gravitation, and the generation and interactions of the electromagnetic spectrum. The process by which the historical perspective of science knowledge changes or becomes more complete by evolving over time is highly evident. Evolutionary processes within the universe as described in the *Earth and Space* content standard for grades 9–12 are emphasized. The content dealing with the life cycles of stars covers key concepts related to the *Common Themes and Unifying Concepts,* and the content relating to the classification of radiation and stars by physical properties emphasizes the specific unifying concept of *organization.* This unit stresses the concept that scientific ideas depend on experimental and observational confirmation, and shows students that science helps drive technology as it addresses questions that need more sophisticated instruments, and provides principles for better technology and technique. All students are expected to understand that technology is essential to science, as it enables observations of objects that are otherwise unobservable due to factors such as distance and time. Science and technology are reciprocals, as stated in the *Science and Technology* content standard. Technicians have developed instruments to enable astronomers to "see" the visually unseeable. More refined technological tools with which to observe the universe help all scientists to obtain new information and to revise their ideas accordingly. Utilizing specialized technology to collect and analyze data, determining a classification system, and plotting properties in graphical form enables scientists to understand large-scale and long-term phenomena.

Chapter 8: The Nature of Light

Summary

An introduction is given to the basic physics of light and the rest of the electromagnetic spectrum, the means by which astronomers learn about the universe. The forms of electromagnetic radiation differ only in wavelength, but this dramatically affects their properties and the methods that we use to detect them. Light is composed of a full spectrum of colors which gives information about the stars. As light is emitted from the surface of stars into space it follows the inverse square law relationship.

Terminology

antisolar point	inverse square law	skyglow
absorption lines	light pollution	spectroscopy
Balmer series	Lyman series	spectrum
dispersion	microwave band	wavelength
electromagnetic radiation	photons	wave-particle duality
emission lines	reflection	
ground state	refraction	

Common Misconceptions

1. *Light is clear and prisms or gratings "add" color.*
2. *There is a linear relationship between distance and apparent brightness.*

SUGGESTIONS FOR POSTER PAGES, INVESTIGATIONS, AND ACTIVITIES

Investigation 8.1: The "Flavors" of Light

Color is important in stellar analysis. Give the students an assortment of objects with which to investigate light. Feathers, prisms, diffraction gratings, and hand-held spectroscopes are good tools. For younger students, feathers are a fine introduction to the spectrum, as they make excellent "prisms" and produce a spectrum when light passes through them. (They can be obtained from hobby shops or craft stores, or from pillows.) Have the students look closely at the feathers (later on they may conclude that the fine, interlocking structures are similar to a diffraction grating and that the fine lines allow the colors to separate), and then turn on a light bulb and have the students examine how light is affected by its passage through the feathers. Does rotating the feathers change the colors? Are big feathers better than smaller ones? What colors are seen? Do they change? Have student write descriptions and draw colored pictures of what they see and then discuss their results with the rest of the class.

Students can also look through diffraction gratings (see Resource List for details). If they do, have different light sources available, such as incandescent and fluorescent. Have them experiment with prisms. They can draw spectra they have observed using feathers, gratings, and prisms and compare the results. Which one produces the "best" range of color? NOTE: A clear, cylindrical, refrigerator bulb (with a linear filament) works very well with transmission gratings. RESOURCE

At this time you may want to introduce a hand-held spectrometer, which not only separates light into its spectrum of colors, but also shows the intensity of each of the colors present. This will be investigated further in the spectroscopy activity below, and in even greater detail in analyzing stellar spectra in following chapters. Older students may not need the investigation as an introduction. Inexpensive spectrometers can be obtained from Project Star (see Resource List for details). RESOURCE

Core Activity 8.2: Spectra of the Elements

You will need spectroscopes, spectrum tubes of elemental gases, and a voltage source for part A of this activity. The Project Star spectroscopes work well. Physics labs usually have spectrum emission tubes and voltage sources. If the spectrum tubes are not available, then have students look at different light sources around the school and at home. They will still be able to do part B. You can either make transparencies of the individual spectra for them to overlay on the mixed spectra, or they can simply fold the paper for each individual spectra and place them above or below the mixed spectra to match up the spectral lines.

Answers to Spectra Identification Problems

1. Hydrogen and magnesium.

2. Hydrogen, helium, and lithium.

3. Nitrogen and mercury.

4. Neon and iron.

5. Nitrogen, lithium, and iron.

Core Activity 8.3: The Inverse Square Law

Unless you are dealing with older students, precut the squares in the paper and the cardboard. The edges must be sharp and smooth or the outline of the illumination of light on the grid will be difficult to see, and the room must also be quite dark. Templates are included in the student activity.

Answers to questions:

1. 1/4,1/9, 1/16, 1/25
2. 1/100
3. 4, 9, 16, 25, 100
4. 1600

Poster Page: Inverse Square Relationships

Most students perceive the change in intensity of a light source with distance as linear. We are so used to thinking of light as moving in straight lines that we forget light leaves a source in all directions. In textbooks the movement of light is usually designated as one or two rays represented as arrows, which further reinforces the misconception. Light is only one part of the electromagnetic spectrum. All parts behave in the same way, from radio waves to X-rays and gamma rays. The inverse square law applies to any equation that has distance squared in the denominator, though students often fail to recognize similarities among equations. Electrical forces, gravitational forces, and EM radiation all decrease with the square of the distance, whether the distance is in light-years, kilometers, or angstroms. Radii also are distances; the larger the radius of a star, the larger the surface area and the less radiation that leaves per unit area. The apparent size also varies inversely with distance. The students are given the equations for electrical and gravitational forces.

Poster Page 4.2, “Astrology or Astronomy?” discusses horoscopes and the supposed influence of stars and planets in determining human characteristics and destinies. Have students use Newton’s Law of Universal Gravitation and plug in the numbers for the planet associated with their horoscope. Then they can use other planets, the Sun, or people, and calculate how much gravitational force these different objects exerted on them at the moment of their birth. The results are always interesting.

Activity 8.4: Light Pollution

The International Dark Sky Association (IDA) has a set of slides available concerning light pollution. They will also provide a complete set of articles and information for a very reasonable price. (See Resource List for details.) From other sources you can also obtain remarkable satellite photographs of the Earth at night, which graphically depict the extent of light pollution. (See Resource List for details.) Students can study light pollution problems in their own location. Students can determine related factors such as the energy cost of inefficient lighting, the politics and budgetary considerations to improve lighting and reduce light glare and trespass, city lighting ordinances, the effect of lighting on crime levels, and psychological factors dealing with lighting. Who establishes criteria for lighting? What factors are considered? The IDA materials are a rich resource for these types of research. Your students might initiate a study and approach the local government to try to change a light pollution problem in their area.

RESOURCE