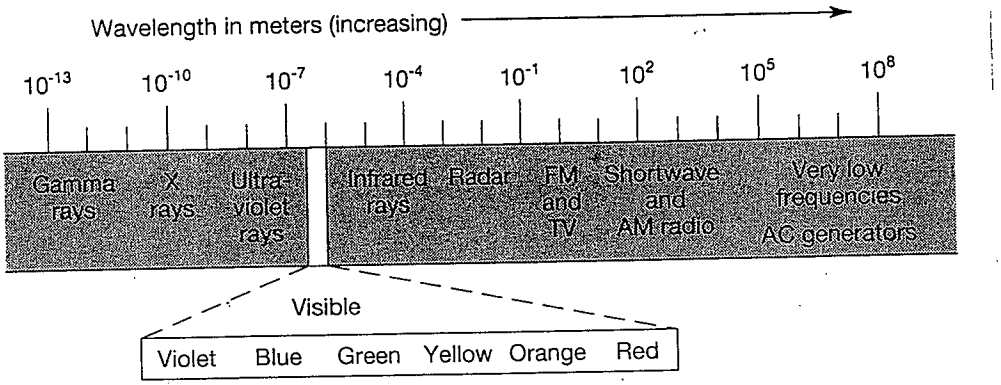
Teaching Activity: Spectral Messages

Introduction: Most of what scientists have learned about the cosmos, or the world beyond the Earth, has been acquired via the various wavelengths of the electromagnetic spectrum. The unaided human eye, given clear skies and no glare from surrounding lights, is capable of sighting approximately 6000 stars in the night sky. Included in this celestial view are our own star, the Sun, the moon, and the nearby planets.

Telescopes, which came into general use in the seventeenth century, greatly extended the range of discovery using visible light. The Hubble Space Telescope, which was put into orbit in 1990, moved our vantage point above the distortion of the Earth's atmosphere. Unfortunately, a 2 micrometer error (a micrometer is less than the width of a human hair) in the telescope's mirror caused fuzzy images. Computer processing was able to correct the problem and many enlightened photographs have been transmitted to Earth, In many cases the Hubble images have shown that what was thought to be a single star is in fact many stars. The diagram below shows the small region of the electromagnetic spectrum occupied by visible light.



All matter, unless at a temperature of absolute zero, emits electromagnetic energy. Any given spectrum is the record of energy transactions for the source producing the spectrum. Astronomers can read much from the spectra of stars. The chemical composition of a star's atmosphere, its temperature, pressure or density, magnetism, and motion can be interpreted from the various types of spectra produced.

The spectra from a variety of energy sources can be observes using a spectroscope. The diffraction grating used in one type of spectroscope has thousands of grooves per centimeter. The diffraction grating breaks down or refracts the incoming light into its component colors. Other spectroscopes use prisms and lenses to produce spectra. Isaac Newton used prisms to produce spectra in the 1600's. A combination of genius, lens-making technology and mathematics led Newton to the following revolutionary conclusion, which he stated in a letter written in 1672:

> "Hence therefore it comes to pass, the **Whiteness** found is the usual **Colour** of **Light**; for Light is a confused aggregate of Rays induced with all sorts of Colors, as they are promiscuously darted from the various parts of luminous bodies."

Materials: Spectroscopes, energy sources, spectral tubes and power sources, lab sheet, paper/pencil, colored pencils;

Procedure:

1. If using tubular student spectroscopes, look through the end with the circular eyepiece. The opposite end has a slit which is pointed toward the energy source. To observe a spectrum, rotate the spectroscope until a spectrum appears on the side wall on the inside of the spectroscope. Turn the cap at the slit end of the spectroscope to widen the spectral bands. **CAUTION: When viewing the solar spectrum, do not point the spectroscope directly at the Sun.**

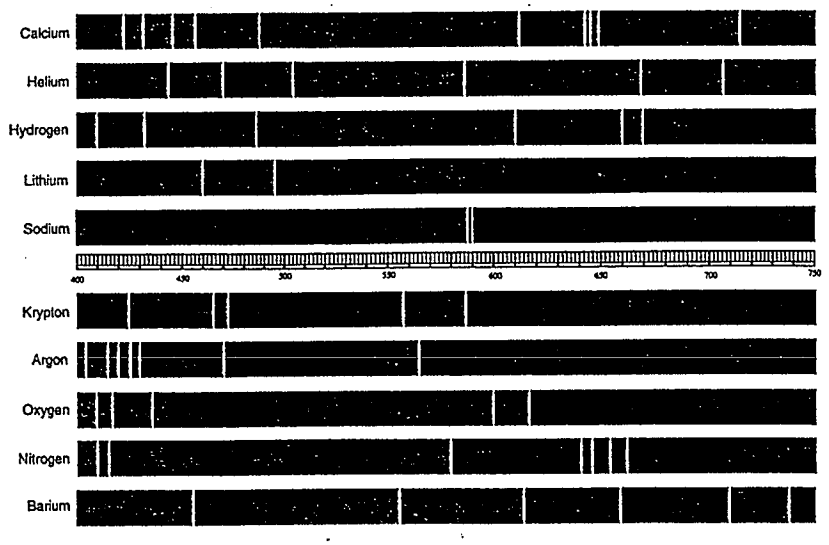
2. Observe the solar spectrum. The absorption spectrum produced by the Sun includes several colors. Draw this band of colors in the space provided in the worksheet.

3. Use the spectroscope to observe a clear, incandescent light bulb. This energy source will produce a continuous spectrum, in which countless atoms collide to produce bland of colors. It is not possible to distinguish the energy levels of different atoms in this type of spectrum. Record the appearance of the spectrum in the space provided.

   (NOTE: Although the solar spectrum you observed looks similar to this continuous spectrum, the solar spectrum actually has small, dark absorption lines that your spectroscope may not show. These dark lines are caused by the absorption of photons by the cooler, outer atmosphere of the Sun. Dark lines appear at various points in the spectrum depending on the wavelength absorbed.

5. Observe a fluorescent light source. This light source displays a bright-line spectrum that is produced by hot gases of low density. The bright lines are determined by the kinds of atoms in the heated gas. Each gas has a characteristic bright-line spectrum. Draw this spectrum in the space provided.

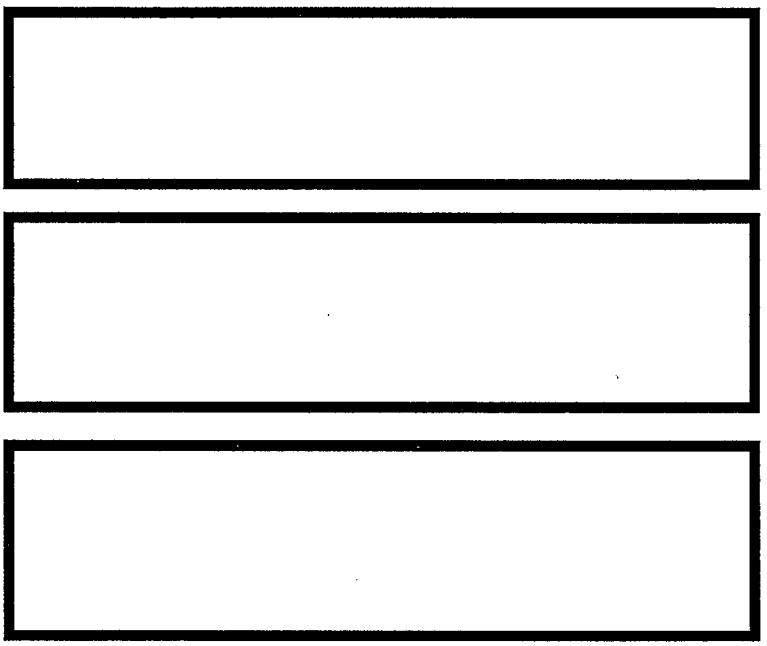
6. Choose any 3 of the spectral tubes to observe. These spectra will be formed by heating a sample of an element to a high temperature. Draw the spectra observed in the spaces provided. Below are examples of the spectra of various common elements.



Student Activity Sheet #1: *Spectral Messages*

Part I: Observations:

Energy Sources:

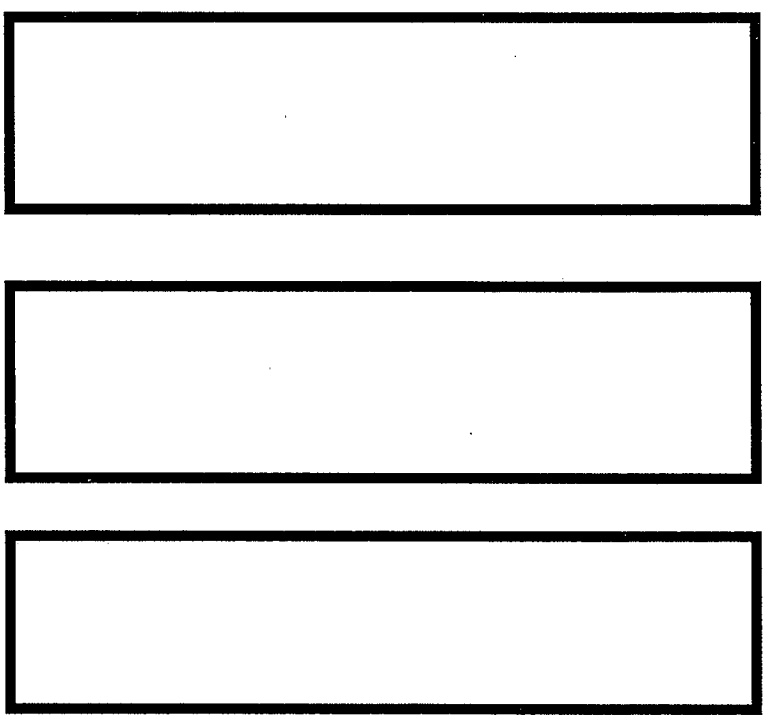


Solar

Incandescent

Fluorescent

Bright-line Spectra:



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Student Activity Sheet #2

Part II: Analysis and Conclusions

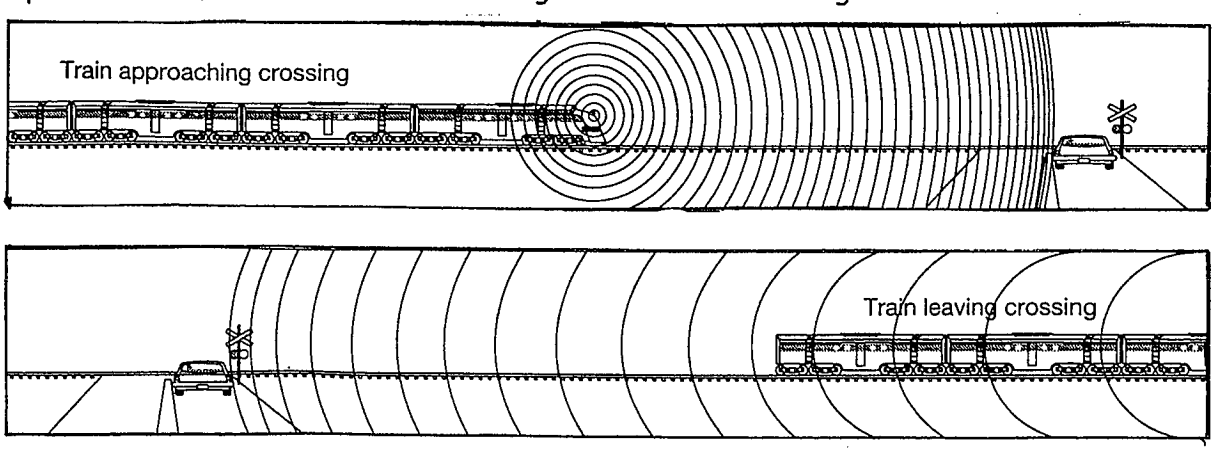
1. List the colors, from longest to shortest wavelength, observed in the solar spectrum.

2. How is the spectrum of the fluorescent source different from the spectrum of the incandescent source?

3. What do the dark lines in the absorption spectra of stars indicate?

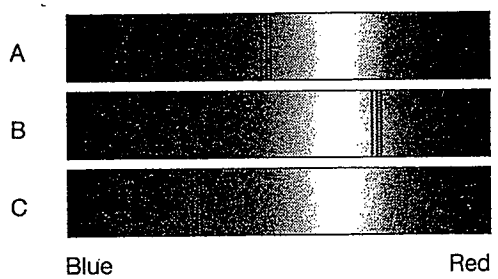
4. Why are the bright-line spectra helpful in determining the chemical composition of stars and other heated matter?

5. The motion of a star toward or away from Earth may be determined by analyzing the spectra produced by the star. Both sound and light waves show shifts in wavelength due to changes in direction of motion between the observer and the sound or light source. This shift is known as the ***Doppler effect***. The figure below illustrates this effect with sound waves produced by an approaching train. The compressed, or shorter, wavelengths produced as the train approaches cause a higher pitched sound. The extended, or longer wavelengths, produced by the departing train cause a lower pitched sound, as heard in the car waiting at the railroad crossing.



Student Lab Sheet #3

Spectrum A in the figure below represents the spectrum of a star moving toward or away from the Earth. Spectra B and C represent stars that are moving in relation to the Earth. Which spectrum represents a star moving away from the Earth? How do you know?



6. How do AM radio and television wavelengths compare with radar? With X rays?

7. The figure below shows the spectra of 4 common elements. Spectrum M was recorded by observing a high-temperature sample of an unknown material. What elements are present in this unknown material? How do you know?