PROJECT STAR

Activities for the Spectrometer

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The Spectrometer
Measuring the Universe with Color

Background Information

Isaac Newton discovered that when sunlight enters a piece of glass with non-parallel sides (a prism) the colors of the rainbow (a spectrum) came out the other side. When a prism, used in a device called a spectrometer, is connected to the end of telescope, the spectrum of a star can be studied. The following is just a partial list of physical properties learned about analyzing the spectra of planets, stars, or galaxies: chemical composition, speed toward or away from Earth, rotation speed, temperature, density and turbulence of an atmosphere.

Another device for separating the light from a source into its spectrum is a diffraction grating. The grating consists of a transparent material onto which hundreds of lines per centimeter have been etched. As the light passes through these lines, different wavelengths of light (different colors) are bent at different angles. Many modern spectrometers make use of grating instead of prisms. The purpose of this activity is to use a diffraction grating spectrometer to identify various light sources by observing their spectra and recognizing the chemical composition of the Sun.

MATERIALS

- 1 spectrometer
- 1 incandescent lamp (light bulb that emits light by a glowing filament)
- 1 fluorescent lamp (light bulb that emits light by a glowing gas and glass coating)
- colored pencils or pens
- white surface, such as a movie screen or wall

PROCEDURE

1. In an illuminated room, hold the spectrometer in a manner such that you can read the printing on the body of the spectrometer. The narrow end of the spectrometer should be facing you. The narrow end has a plastic disk that holds the diffraction grating. Hold the spectrometer such that the diffraction grating is near to one of your eyes. As you look through the spec-

trometer you should see a vertical line to your right and a scale of numbers to your left. The vertical line to your right has a thick and narrow width. The scale to the left indicates wavelength of light in nanometers (nm) and in corresponding energies expressed in electron Volts (eV). As you move your head and spectrometer around you may notice different colors appear and disappear on the left side of the scale.

2. Turn on an incandescent light bulb, keep the room lights on, and look at

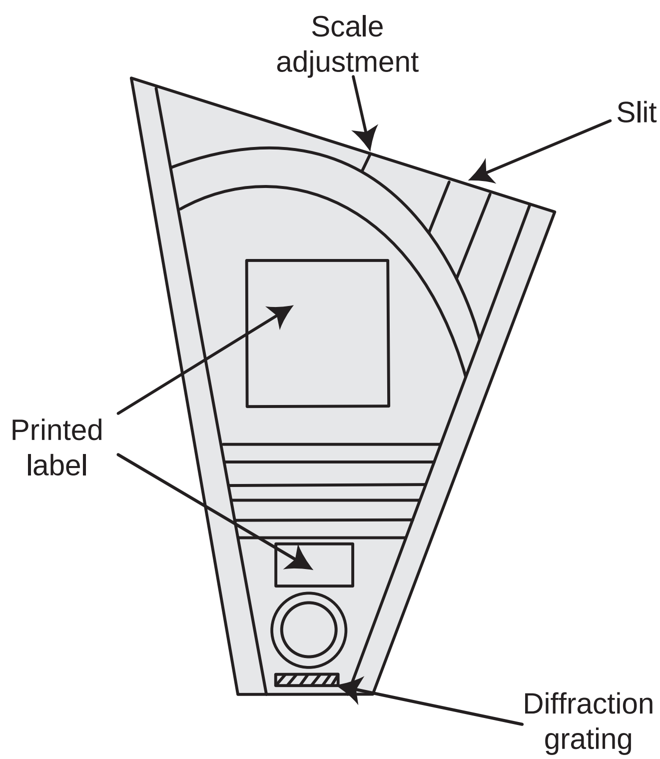


Figure 1

the bulb through the spectrometer. Be careful to aim the slit (on the right side of the spectrometer) at the light bulb and look straight ahead at the spectrum on the scale. You should see a continuous spectrum of colors from red through violet. Mark on the scale below, Figure 1, the colors you see where you see them. Use colored pencils to shade in the observed colors.

3. Read the number on the scale corresponding to the light farthest to the right that you can see and the number corresponding to the light farthest to the left that you can see.

a) The observed spectrum extends from ____________________nm to ________________nm.

b) The colors at these places on the scale are: ______________ and ______________.

4. Now look at a fluorescent light through the spectrometer.

a) Describe the spectrum you see. Is it different from the spectrum that you observed in Step 1?

5. Again record the ends of the spectrum.

a) The observed spectrum extends from ________________nm to ______________nm.

b) The colors at these places on the scale are: ______________and ______________.

The spectrum from the fluorescent light should include several bright vertical “lines”. These are images of the slit. Indicate the positions of these lines on the scale below, Figure 2.

6. Read the positions of the bright lines on the scale and record them in Table 1.

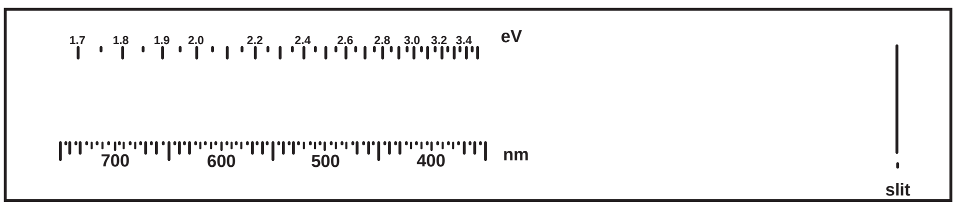


Figure 2

7. The most common type of fluorescent light will have the mercury emission lines superimposed on a continuous spectrum. The green line of mercury occurs at 546 nm. If your value in Table 1 does not agree with this standard value, adjust the position of the scale in your spectrometer.

8. Point the slit of your spectrometer at a white surface that has fluorescent light shining on it, such as a wall or a movie screen, and measure the ends of the spectrum and the positions of any bright lines that you see. Record your data in Table 2.

Color	Position (nm)

Table 1

Color	Position (nm)

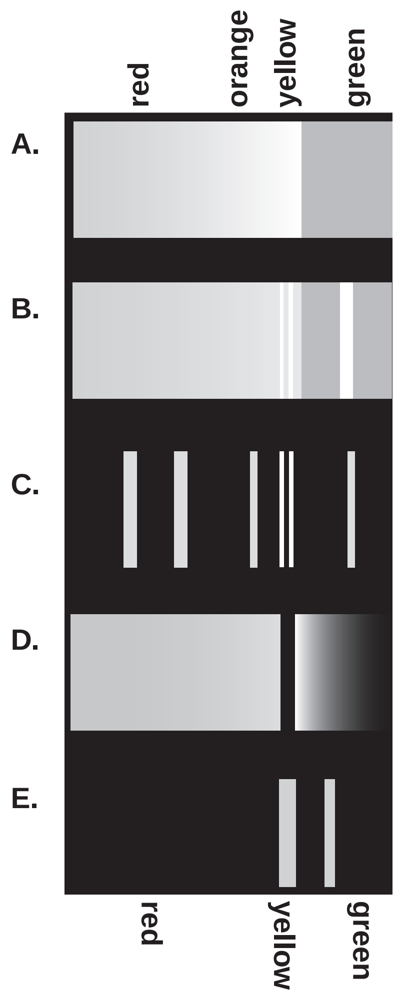
Table 2

a) Compare the results of Steps 5 and 6. Was the spectrum that you saw from the fluorescent light similar to or different from the spectrum you saw when you looked at the white surface?

b) Why do you think the spectra were similar or different?

9. Use your spectrometer to observe as many other light sources as you can find. Suggested lights include the red or green LEDs (Light Emitting Diodes) on a DVD (Digital Video Disk) Player or stereo system; chemical light sticks; and ordinary light bulbs observed through transparent, colored objects.

List the object and describe the spectrun
or dark lines in the spectrum? If there ar
positions and the colors of the lines.)



Object 1:

Description of spectrum:

Object 2:

Description of spectrum:

Object 3:

Description of spectrum:

10.You will now identify the spectrum of some unknown lights. Observe the spectra of some indoor lights and a few street lights or security lights. Write the letter of the observed spectrum (on the left) on the blank that corresponds with the type of light (and its apparent color) on the right.

11.During the daytime, take your spectrometer outside to a shady area where you can still view the sky (or look through a window from a darkened room) and point the slit toward an area of bright sky.

DO NOT LOOK DIRECTLY AT THE SUN!!
IT CAN DAMAGE YOUR EYES!!

You should see a continuous spectrum with the addition of some dark vertical lines at certain wavelengths. Measure the ends of the spectrum.

a) The observed spectrum extends from ______________nm to ______________nm.

b) The colors at these places on the scale are: ______________ and ______________.

Now measure the positions of the dark lines that you see. Record the results in Table 3.

12.Compare the dark lines you observed in the Sun's spectrum with those listed in Table 4.

a) What elements do you conclude are present in the Sun?

b) Do you think that you have found all the elements that are in the Sun?

Missing Color	Position (nm)

Table 3

Why or why not?

ABSORPTION LINES IN THE SUN

(from the ***CRC Handbook of Chemistry and Physics***)

Line	Due to (nm)	Wavelength	Line	Due to (nm)	Wavelength
M	Iron	372.8	b4	Iron	516.8
L	Iron	382.0		Magnesium	516.7
K	Calcium	393.4			
H	Calcium	396.8	b2	Magnesium	517.3
h	Hydrogen	410.2	b1	Magnesium	518.4
g	Calcium	422.7	E2	Iron	527.0
			D2	Sodium	589.0
G	Iron	430.8	D1	Sodium	590.0
	Calcium		C	Hydrogen	656.3
G'	Hydrogen	434.0	B	Oxygen	759.4
F	Hydrogen	486.1		Oxygen	762.1

Table 4

c) Where do you expect that elements would have to be located in order to cause dark absorption lines in the spectrum of the Sun? (Would they have to be located inside the Sun, on the Sun's surface, above the Sun's surface, in space between the Sun and the Earth, or in the Earth's atmosphere?)

13. Point the spectrometer slit at a bright, white cloud.

a) Describe the spectrum that you see. How does the "cloud" spectrum compare to the spectrum of the Sun? Does the cloud spectrum have dark lines as the solar spectrum does?

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b) Why do you think the cloud spectrum appears the way it does?

14. Look at the Moon through the spectroscope. (This activity is best done at night when the Moon is bright compared to the background sky, such as when there is a full Moon visible two or three hours after sunset.)

a) Describe the spectrum. (How does the Moon's spectrum compare to the spectrum of the Sun? Does the lunar spectrum have dark lines as the solar spectrum does? Are they the same lines? Why or why not?)

15. The purpose of this activity is to study how certain transparent materials will allow some colors of light through and absorb the others. Locate various pieces of colored transparent glass or cellophane or make a colored liquid. The liquid can be made by mixing food dyes and water in a clear glass or plastic container. (Don't forget good experimental practice: Check to see if the "clear" glass absorbs any colors before observing light through a colored liquid in the bottle AND observe the light source to make sure that it is producing all colors).

Place a transparent colored object (glass, cellophane, liquid) between a bright white light source and the spectrometer. For each object, record in Table 5 the following data: the type of object and its color, the missing color(s), and the position(s) of the dark bands on the spectrometer scale. (The dark bands, called absorption bands, are due to photons of certain wavelengths being absorbed by the object. When the photons are absorbed, the colors corresponding to the photon energies are removed from the spectrum and gaps, or bands, show up in the spectrum where the missing colors would have appeared if there was no absorption.)

New Section(s):

Where and in what sequence should this (these) paragraph(s) be included?

What are the "spectral lines"?

Object and Color	Missing Color	Position (nm)

Table 5

The bright lines one sees in the spectrum of the incandescent bulb are images of the slit. If one looks carefully, one can see the wider central part of the slit. If the slit were shaped like the letter "S", one would see bright images of the "S" in the same colors as the lines.

The diffraction grating shows one the colors of light that are mixing together to produce the one color that you see when when one looks at the light with out the diffraction grating. If you hold a piece of shear drapery material at arms length between you and an illuminated lamp, one will see colors spreading out from the source perpendicular to the threads in the fabric. The colors are produced by the interference of the waves of light that exit the fabric. Different colors, or different wavelengths, of light interfere at different places producing the spectrum or rainbow of color.

The different "bright lines" of "emission lines" are characteristic of different gases. Each color represent a specific transition of electrons in the outer shells of the atoms of the gas. Energy in the form of heat or electric fields make the electrons in lower energy levels jump to higher energy levels. The electrons then fall to lower energy levels emitting a specific color or energy of light. Different gases exhibit different emission spectra which indicate the unique structure of the energy levels for the electrons that surround the nucleus of the atom.

When one observes the light of a luminous (emitting light) object through a spectrometer, one can observe three different kinds of spectra.

1. If the light from a heated solid, or a fluid substance under high pressure (an incandescent object), is observed through a spectrometer one will see all colors of the visible spectrum from RED to VIOLET (ROYGBV). This is called a continuous spectrum. One will see variation in the brightness of various colors depending on the temperature of the heated object. The lower the temperature, the more red is seen in the spectrum.
2. If the light from a low pressure gas is observed through a spectrometer one will see bright emission line at specific colors that are characteristic of the gas. This is called an emission spectrum. If the pressure of the gas is increased the emission lines will broaden and change.
3. If the light from an incandescent object passes through a low pressure gas, one will observe dark line or absorption lines at the specific colors that the gas would normally produce emission lines. This is called an adsorption spectrum. The low pressure gas absorbs its characteristic colors for the continuous spectrum of light passing through the gas.