NOTE: Use the diffraction grating disk for the first part of the spectrometer activity and then complete its construction.

Materials -(included in kit)

- 2 cardboard sections (top and bottom)
- 2 foam side pieces
- 5 pairs of nuts and screws
- 1 film strip scale
- 1 plastic disk with diffraction grating
- 1 support tube (3/4")

Procedure

1. Lay one of the spectrometer body sections on a level table with the narrow end towards you and the pointer on your right. (Figure 1)

2. Lay the longer foam side piece on the left hand side of the body section such that the two screw holes are covered and the outside edge of the foam is even with the outside edge of the body section. Position the shorter foam piece in a similar fashion on the right hand side of the body section. All four holes should be covered by the foam pieces. Stand the diffraction grating disk in the wide slit at the narrow end of the body section. Stand the support tube (3/4") centered over the screw hole in the middle of the cardboard section. (Figure 2)

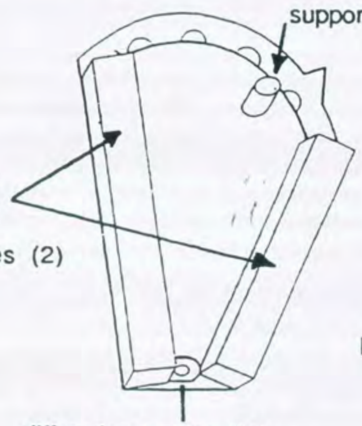


Figure 2

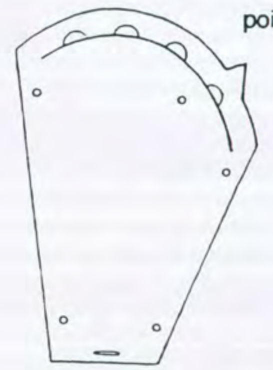


Figure 1

(note the side **with** the plastic film should face **into** the spectrometer **not** toward your eye)

3. Position the other body section over the arrangement on the table. Lay it on the foam pieces such that the top of the grating disk fits into the wide slit on the narrow end of the upper body section. Make sure that the body sections are parallel to each other. This means that the pointer must be on the RIGHT hand side!!! Fit the screw through the support tube as illustrated and put the nut on it. There are no holes in the foam. Therefore, you must push the screws through each hole, the foam, and out the other side. Tighten the nuts over the screws.(Figure3)

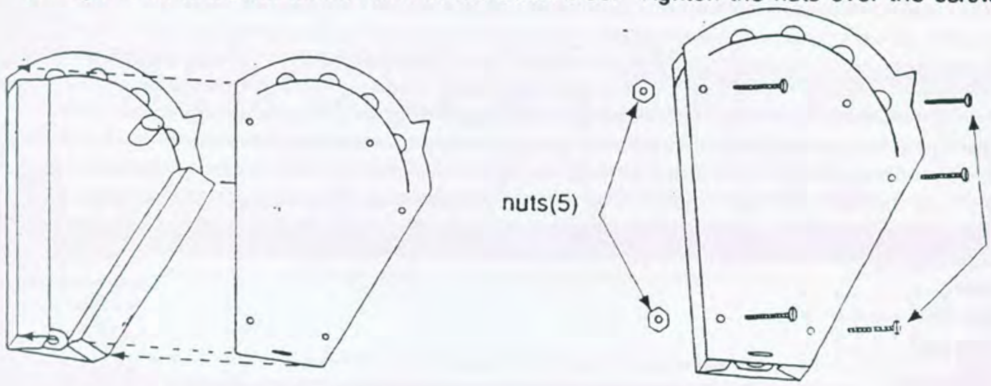


Figure 3

4. Hold the spectrometer body with the pointer to the right. Slide the film strip into the curved slot on the wide end of the spectrometer. Keep the vertical slit on the film strip to the right. The transparency should be positioned so that the sprocket hole of the film just protrudes beyond the top and bottom of the spectrometer body. Apply the label to the TOP of the spectrometer. Follow the instructions in the activity and on the label to adjust the film strip for the proper colors. (Figure 4)

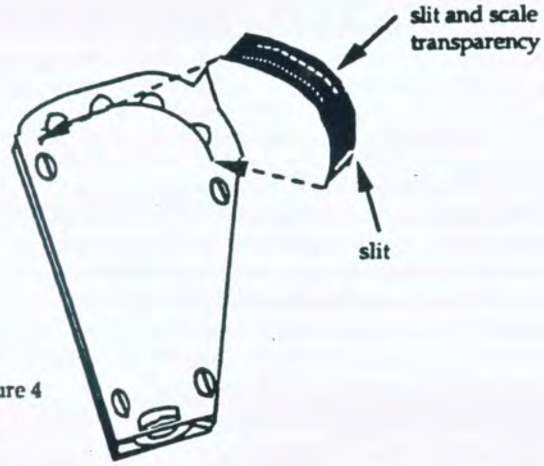
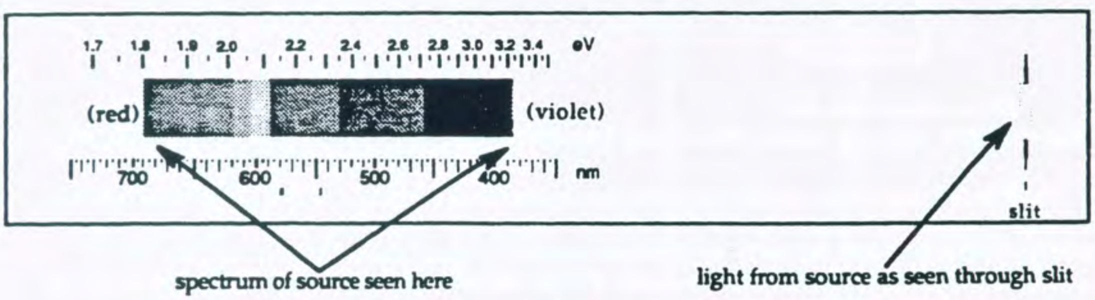


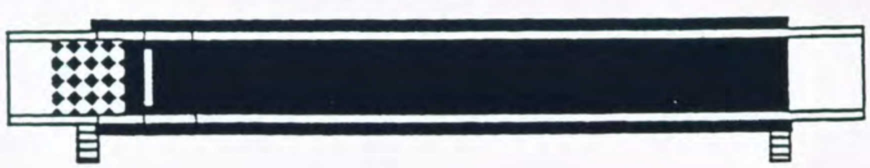
Figure 4

5. When held to the eye and viewed through the small circular opening on the grating disk, you should see the scales reading from left to right and the vertical slit on the right. To view the spectrum of a light source, put your eye to the grating and aim the pointer at the source. Adjust the position of the spectrometer until the vertical slit is illuminated by the light source. (Figure 5)



6. Rotate the grating disk so that the spectrum of the source is horizontal to the left of the slit between the two scales. (Figure 5)

Note to Spectometer Users: Please use the Black Tape that is Securing the film to the spectrometer to cover up the gap between the foam and the film. Placement of the tape is indicated by the checkered area shown below. This should stop any excess light from entering the spectrometer. Don't cover up the slit which lets the light in.



THE SPECTROMETER - MEASURING THE UNIVERSE WITH COLOR Activity 2

Isaac Newton discovered that when sunlight passed through 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.

FUNCTION OF THE DIFFRACTION GRATING

A diffraction grating is a device that takes light from a source and allows an observer to see what colors are mixed together to produce the color seen by the eye. Your diffraction grating is a hologram that produces a very bright spectrum of a source.

1. From the spectrometer kit, take out the plastic disk to which is glued the diffraction grating. Hold it next to your open eye (close the other eye). You will see streaks of color coming from every light and brightly illuminated object in the room. Rotate the disk. As the disk rotates, you should see the streaks of color rotate.

2. Look at an ordinary light bulb (incandescent light) through the grating disk. Rotate the disk such that the spectrum of the light is going to your left and right (not vertical).

   a) Describe and/or draw what you see.
   (Do you see colors? What color is closest to the bulb? Are there colors on both sides of the bulb?)

3. Look at a fluorescent light.

   a) Describe and/or draw what you see.

What you SHOULD have seen...

The light bulb should produce a continuous line of color from red-orange-yellow-green-blue-violet coming out from the bulb with violet being the color closest to the bulb. This is the SPECTRUM of the light. The width of the line of color should appear as wide as the source of light. This is a CONTINUOUS spectrum blending from Red, Orange, Yellow, Green, Blue, to Violet (ROYGBV). Any heated solid will produce this kind of spectrum.

The fluoresescent bulb will also produce a spectrum, as wide as the fluorescent bulb, BUT you should also see images of the lamp in the yellow, green and violet parts of the spectrum. The continuous spectrum is caused by the fluorescent salt coating on the inside of the tube. The bright images of the lamp are specific colors produced by the gas inside the tube. (The gas is Mercury vapor.)

The spectrometer allows you to view a light source through a thin slit. Instead of a spectrum that is the image of an extended source spread over all the colors, you will see an image of the slit spread over the colors. The spectrometer also has a scale so that specific numbers for wavelength or photon energy can be assigned to specific colors.

Build the spectrometer using the directions in Note 2.

MATERIALS

- 1 spectrometer
- 1 incandescent light bulb (bulb with a glowing filament)
- 1 mercury fluorescent light
- colored pencils or pens
- white surface, such as a movie screen or wall

PROCEDURE

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

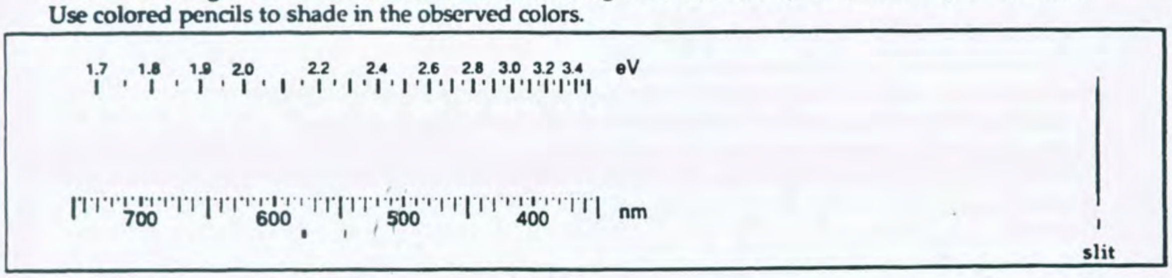


Figure 1

2. 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 _____________ .

3. 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?

4. Again record the ends of the spectrum.

   a) The colored spectrum extends from ___________ nm to ___________ nm.

   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.

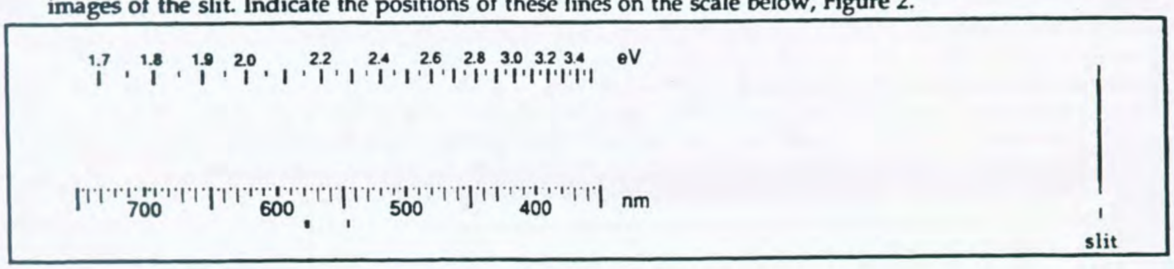


Figure 2

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

Color	Position (nm)

Table 1

6. 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.

7. 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 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?

8. 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 VCR (Video Cassette Recorder) or stereo system; chemical light sticks; and ordinary light bulbs observed through transparent, colored objects.

List the object and describe the spectrum you observed.
(Are there any bright or dark lines in the spectrum? If there are any bright or dark lines, give the positions and the colors of the lines.)

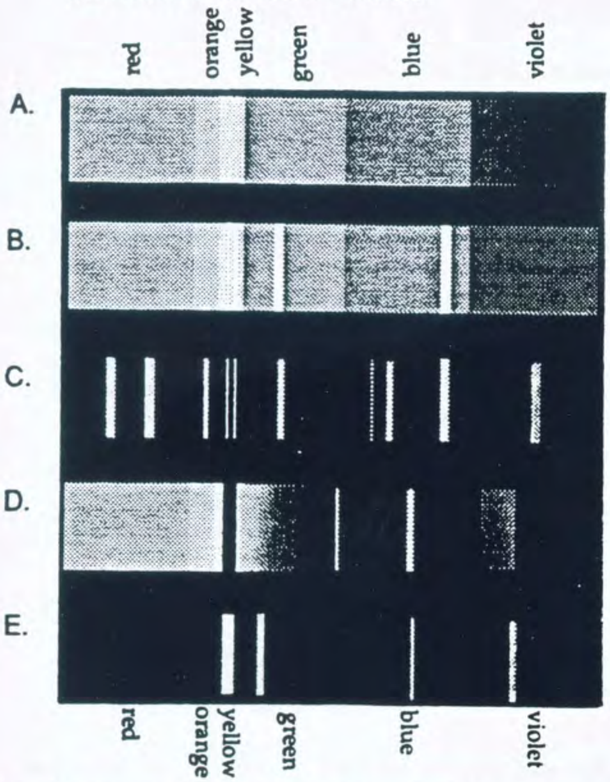
Object 1: ______________________________
Description of spectrum:

Object 2: ______________________________
Description of spectrum:

Object 3: ______________________________
Description of spectrum:

9. 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.

SPECTRA OF SELECTED LIGHTS



TYPE OF LIGHT (appearance to naked-eye)

_______ incandescent light bulb (yellow white)

_______ high pressure sodium (orangish yellow)

_______ fluorescent light (bluish white)

_______ low pressure sodium (yellow)

_______ mercury vapor (blue)

10. Take your spectrometer outside (or look through a window from a darkened room) and point the slit toward the bright sky near the Sun.

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

You should see a spectrum of all the colors with narrow, dark lines superimposed. Measure the ends of the spectrum.

a) The spectrum extends from ___________ nm to ___________ nm.

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

Missing Color	Position (nm)

Table 3

11. Compare the absorption 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? Why or why not?

    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?)

12. 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?

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

13. 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?)

Table 4

ABSORPTION LINES IN THE SUN
(from the *CRC Handbook of Chemistry and Physics*)

Line	Due to	Wavelength (nm)	Line	Due to	Wavelength (nm)
M	Iron	372.8	b_4	Iron	516.8
L	Iron	382.0		Magnesium	516.7
K	Calcium	393.4			
H	Calcium	396.8	b_2	Magnesium	517.3
h	Hydrogen	410.2	b_1	Magnesium	518.4
g	Calcium	422.7	E_2	Iron	527.0
			D_2	Sodium	589.0
G	Iron	430.8	D_1	Sodium	590.0
	Calcium		C	Hydrogen	656.3
G'	Hydrogen	434.0	B	Oxygen	759.4
F	Hydrogen	486.1		Oxygen	762.1

OPTIONAL ACTIVITY

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.)

Build your celestial sphere using Note 3 as a guide

Object and Color	Missing Color	Position (nm)

Table 5