Project STAR Spectrometer

P2-7055

INSTRUCTIONAL GUIDE

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- Project STAR Spectrometer
- Instructional Guide with activity

Required for this lab but not included:

- Incandescent light source
- Fluorescent light source
- A variety of other sources
- Colored pencils
- White surface
- Colored filters or colored water

Background

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.

Introduction

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 and an emission spectrum is seen. This spectrum is able to be superimposed over a scale which is proportional to the wavelength of the light being emitted. 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.

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Activity: Measuring the Universe with Color

1. In an illuminated room, hold the spectrometer in a manner such that the printing on the body of the spectrometer is facing down and the wide end is facing away. Hold the spectrometer such that the diffraction grating in the narrow end is near to one of your eyes. As you look through the spectrometer 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.

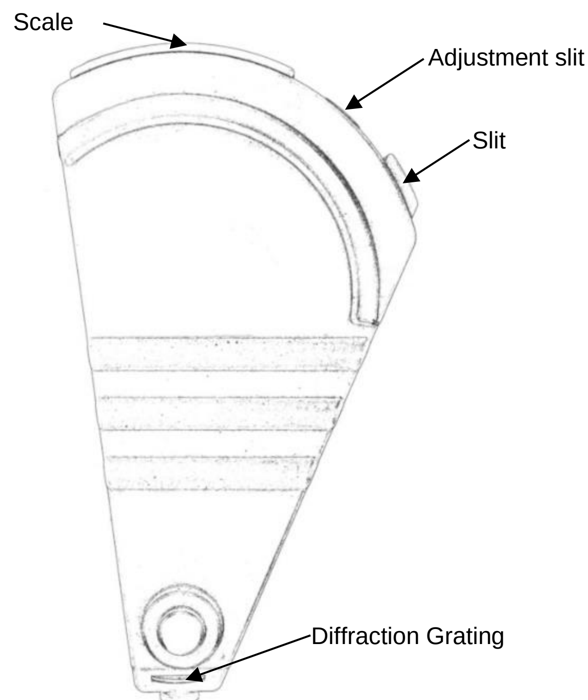
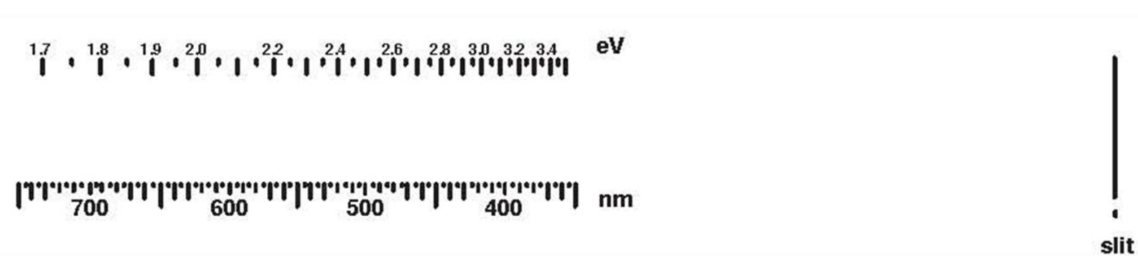


Figure 1

2. 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.



3. Record the longest and shortest visible-color wavelengths. What colors correspond to these wavelengths?
   a. The observed spectrum extends from _________ nm to _________ nm.
   b. The colors at these places on the scale are _____________ and _____________.

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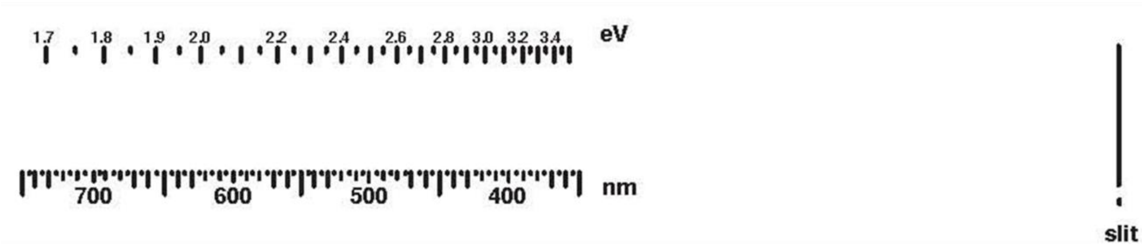
4. Now look at a fluorescent light through the spectrometer. Describe the spectrum you see. Is it different from the spectrum you observed in step 1?

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 a fluorescent light should include several bright vertical "lines." These are images of the slit. Indicate the positions of these lines on the scale below.



6. Read the positions of the bright lines on the scale and record them in Table 1.
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 the value in Table 1 does not agree with this standard, the spectrometer may need to be calibrated (see "Calibration" section).
8. Point the slit of your spectrometer at a white surface that has a fluorescent light shining on it such as a wall or movie screen. Measure the ends of the spectrum and the positions of any bright lines you see. Record your observations in Table 2.

Table 1. Direct observation of fluorescent light

Color	*Wavelength (nm)*

Table 2. Reflective observation of fluorescent light

Color	*Wavelength (nm)*

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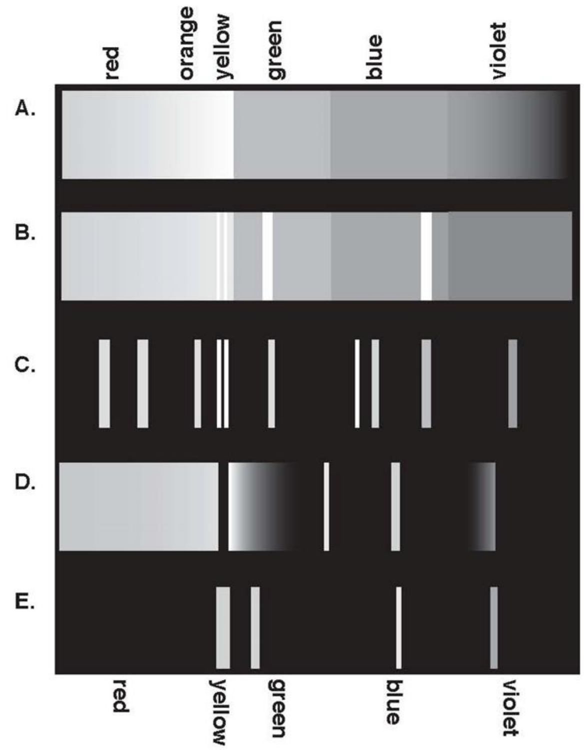
9. Was the spectrum you saw from direct observation of the fluorescent light similar or different from the spectrum you saw when you looked at the white surface? Explain why.

10. Use your spectrometer to observe as many other light sources as you can find. Some suggestions are: red or green LEDs, chemical light sticks, ordinary light bulbs viewed through transparent, colored objects, gymnasium lights, or white clouds.



List the name of the object you choose and describe the type of spectrum you observe from it. Use the diagram above to help describe what you see. Explain what features of the spectrum you observed led you to your conclusion.

Object 1:
Description:

Object 2:
Description:

Object 3:
Description:

Continue on a separate sheet of paper if needed.

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

DO NOT LOOK DIRECTLY AT THE SUN

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 _____________.

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

Table 3. Observation of the solar spectrum

Color	*Wavelength (nm)*

13. 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 you have identified all the elements present in the Sun?

Table 4. Absorption lines in the sun (from the CRC Handbook of Physics and Chemistry)

Element	*Wavelength (nm)*	*Element*	*Wavelength (nm)*
Iron	372.8	Iron	516.8
Iron	382.0	Magnesium	516.7
Calcium	393.4	Magnesium	518.4
Calcium	396.8	Iron	527.0
Hydrogen	410.2	Sodium	589.0
Calcium	422.7	Sodium	590.0
Iron	430.8	Hydrogen	656.3
Hydrogen	434.0	Oxygen	759.4
Hydrogen	486.1	Oxygen	762.1

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c. Where do you expect that the 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 Earth and the Sun or in Earth's atmosphere? Why?

14. Point the spectrometer at a bright, white cloud. Describe the spectrum you see. How does the "cloud" spectrum compare to that of the Sun? Do the same dark lines appear in the spectrum from the cloud? Describe why you think the spectrum appears the way it does.

15. At night, look at the Moon through the spectroscope. Describe the spectrum you see and compare it to that of the Sun and clouds. Do the same dark spectral lines appear? If there are dark lines, are they in the same positions? Explain why you think the spectra are similar or different.

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Calibration

1. The spectrum from a fluorescent light should include several bright vertical “lines”. These are images of the slit. 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 the green line does not line up with the 546 nm, then the Spectrometer must be recalibrated.

2. Calibration is simple. Place the sharp end of a needle or dissection pin into the tiny hole in the scale adjustment slit (middle narrow slit) on the broad end of the Spectrometer. The grid film is adjustable, but will only move a fraction. Adjust the scale enough to bring the green line back into the 546 nm range. Please note, this particular spectrometer has a 5% accuracy value on either side of the 546 nm line. Light sources are not always similar, and the standard calibration lamp use at the manufacturer may differ slightly from the light source you may be using in the classroom.

3. Remember, the film is made of a very light, thin plastic material and should be handled gently. Any tear or separation of the film from the tracks in which the film is placed, will let in more light than intended and the spectrum will not appear.

4. The film is inserted very tightly in the frame and does not need to be calibrated often.

5. The user may have to adjust the film 2-3 times before placing the green line exactly on the 546 nm line. If the user applies different light sources each time the Spectrometer is used, the Spectrometer may have to be calibrated again. Also note: If the Spectrometer is not stored safely and prone to being bumped unnecessarily, it may have to be recalibrated.

Related Products

RSpec Explorer (P2-9505) Digitally capture an individual spectrum, and then compare it to a series of known spectra! The included camera and software make this an easy and inexpensive solution to studying quantitative spectral data in the classroom.

Periodic Table of Spectra (P2-7068) This colorful Periodic Table of Spectra allows your students to clearly see that each element has its own fingerprint. This 1.5 mil laminated poster is 24″ x 36″ and is a high-quality, high-resolution print with brilliant colors.

Spectrum Analysis Classroom Bundle (P2-9502) A classic atomic theory demonstration! Energize the gas and view the characteristic atomic spectral lines with any spectroscope. This complete bundle comes with 13 different gas spectrum tubes and a power supply.

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