14481 Visible Light Explorations

TEACHER GUIDE

Time Allocation:

To prepare this product for an experimental trial should take less than twenty minutes. Actual experiments will vary with needs of students and the method of instruction, but are easily concluded within one class period.

Introduction

Visible light is the portion of the electromagnetic spectrum that our eyes can detect. Most of the time, we consider light to be white. As you explore light with this activity you will find that light really consists of many colors. One of the important properties of light is its wavelength. A chart of electromagnet energy shows that visible light occupies a narrow range of wavelengths. Red light is the longest wavelength we can see and is only about 750 nanometers long. The shortest is the color violet and is about half as long, 400 nanometers. These wavelengths are incredibly short. There are one million nanometers in one millimeter and a quick glance at a meter stick shows that a millimeter isn't very long to begin with.

You will use a technique called diffraction to study the various wavelengths of light. You can see a simple example of diffraction by cutting a short slit in a piece of paper and looking through the slit at a light source. **Do not use the sun as the light source!** You should see narrow bands of color flanking the slit. Diffraction gratings spread out a narrow beam of light so that we can see all of the colors present in the beam. A grating is a transparent material that has evenly spaced regions which are less transparent. Gratings are divided in one direction, like lined writing paper, or in two directions, like graph paper. Each style has particular uses.

You will examine several light sources using three types of diffraction gratings included in this kit. An interesting initial exploration might be to look at a fluorescent light, decorative lights, and other bright objects. Try to find some self-illuminating digital readouts on clocks or timers or other devices. **Do not look at the sun directly or at the reflection of the bright sun from shiny surfaces. This could cause permanent eye damage, and the grating will offer no protection.** The gratings selected for this kit provide the most interesting views among the materials currently available. Use the diffraction gratings in the order they are listed below and make written notes of each observation.

The holographic grating is a high quality, one-dimensional grating in a 2" x 2" slide mount. It is used by placing it near the eye and then looking off, slightly, to one side or the other. The mount should be rotated until it seems to be spreading images right and left rather than up and down.

The diffraction glasses with the brightly colored frames have two dimensional gratings. They are arranged so you can make observations with both eyes at the same time. The same initial activities and cautions apply to these gratings.

The remaining style of grating is a patented new design that offers 3-D viewing under certain circumstances. Examine the same introductory light sources as before. Notice that things having different colors are no longer viewed as though they were all on the same flat surface. Objects appear nearer or farther depending on their color. Color printed materials also respond in the same way. Suddenly, things are leaping off the page or are beginning to look like they are buried in it. The 3-D glasses are a remarkable example of high-precision micro-optics that compresses an inch of optical function into a layer that is a couple of microns thick. Three-dimensional images can be built by color coding the object to be viewed. You can visit the web site of the manufacturer of these unusual gratings, at http://www.chromatek.com. They have many additional images to view right on your computer's color monitor. You'll also find a collection of classroom activities that can be downloaded from the site.

The initial exploration with the gratings should provide a look at a wide variety of spectra. Each spectrum might look like a representation of some or all of the colors in the rainbow. It sounds simple for us to describe the colors of the spectrum as red, orange, yellow, green, blue, and violet. However, this makes it seem that we could color the whole rainbow with just a few crayons. In fact, we cannot really color a rainbow at all, even with the biggest assortment of crayons. If you took the complete visible spectrum and spread it out to fill the length of a football field, you would be quite surprised. Every smallest step of the way from one goal post to the other would bring you to a new color. Clearly, we cannot name all of these separate colors, because there are an infinite number of them. To solve this problem, a particular color can be identified by its wavelength.

The optional activity provides a technique for measuring the wavelengths of light. You can construct a simple spectrometer to make measurements of light spectra from the LEDs in the kit. You will be able to determine the wavelength of the observed light using your experimental data, a calculator with trigonometric functions, and the following equation.

$$\lambda = d \sin[\arctan(B/A)]$$

The variables in the equation are: λ (the Greek letter lambda), which is the wavelength we will calculate; A , the distance from the LED to the grating (which is set at 1000mm); B, the distance from the LED to the virtual image of the spectrum (read in mm); and d, the distance between slits (lines) on the diffraction grating. Since there are 750 lines per mm, d equals 0.001333mm. Your answer will be in millimeters. To convert the wavelength to nanometers, multiply your answer in millimeters by 10^6, or 1,000,000.

Objective

You will explore the wave properties of light using three different types of diffraction gratings, describe the spectra of five Light Emitting Diodes, and observe the spectrum of a light source with a spectroscope that you construct. In an optional activity, you will build a simple spectrometer and measure the wavelength of several light spectra.

Materials Included in the Kit

- 2 Component Mounting Stands
- 2 Battery Holders, 2 - AA
- 10 Resistors, 47 Ohm, $^1/_4$ Watt
- 24 Clip Leads, Assorted Colors
- 2 Holographic Diffraction Gratings, mounted (750 lines/mm)
- 2 Diffraction Glasses, 3-D
- 2 Diffraction Glasses
- 2 LEDs, White
- 2 LEDs, Red
- 2 LEDs, Orange
- 2 LEDs, Yellow
- 2 LEDs, Green
- 1 Teacher's Guide
- 1 Set, Student Study and Analysis copymasters

Materials Needed but Not Provided

- 4 AA Batteries
- 2 35mm film canisters
- 4 Meter sticks (optional)
- 2 Index cards (optional)
- Black construction paper
- Tape
- Knife
- Calculator with trigonometric functions (optional)

Materials Needed per Lab Group

1 Component Mounting Stand
1 Battery Holder
2 AA Batteries
5 Resistors, 47 Ohm, 1/4 Watt
12 Clip Leads, Assorted Colors
1 Holographic Diffraction Grating, mounted (750 lines/mm)
1 Diffraction Glasses, 3-D
1 Diffraction Glasses
1 LED, White
1 LED, Red
1 LED, Orange
1 LED, Yellow
1 LED, Green
2 Meter sticks (optional)
1 Index Card (optional)
1 Set, Student Study and Analysis Sheets

Shared Materials

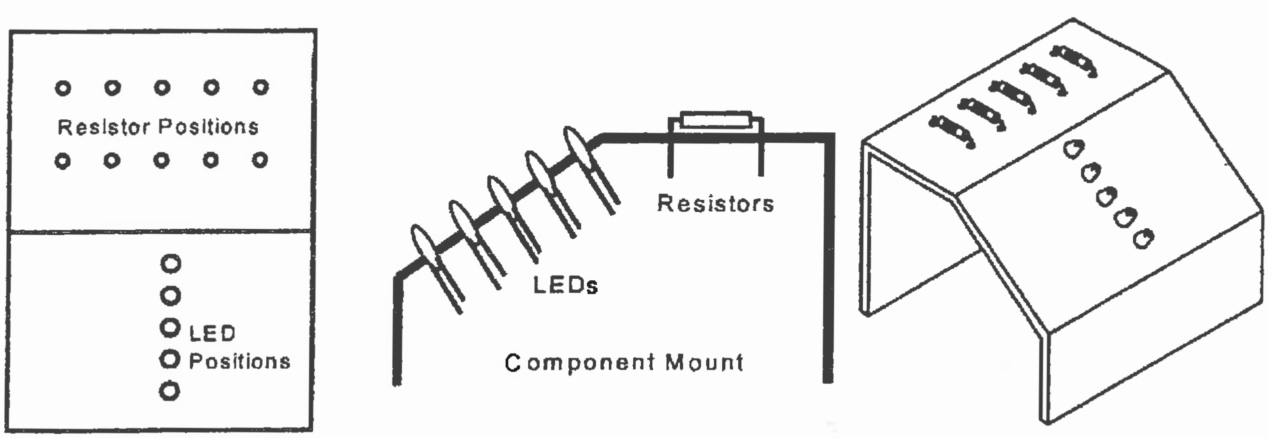
Black construction paper
Tape
Knife
Calculator with trigonometric functions (optional)
Protractor (optional)

Procedure

Construct the Electrical Component Mount

1. Insert the five Light Emitting Diodes (LEDs) into the component mount using the vertically aligned holes on the front of the mount. The diodes are slightly tapered and should wedge in tightly from below. See Fig. 1. The vertical alignment will make each spectrum line up properly with the others no matter which grating is used for viewing.
2. Attach the voltage dropping resistors to the top of the mount. Bend the leads on each resistor so that they fit through the holes. The order and orientation of the resistors does not matter.
3. Leave all component leads full length, but slightly spread apart, to facilitate hooking up the clip leads.

Figure 1



4. Put two AA batteries into the battery pack.
5. Start connecting the LEDs, resistors, and battery pack. The longer lead on each LED is the anode. It should be connected to the positive (+) button on the battery pack using one of the clip leads.
6. The other LED lead should be connected to one of the resistor leads.
7. Connect the second lead of the resistor to the negative (-) button on the battery pack.
8. The LED should now be illuminated. To turn off an LED, disconnect one of its clip leads.
9. There are enough clip leads to connect up to four LEDs at one time. Make sure you have good connections in your circuits or the LEDs will not work.

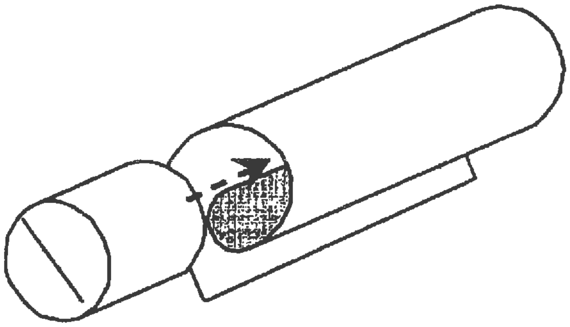
Examine the LED Spectra

1. Connect one of the LED circuits so that it lights up.
2. Look at the LED through each of the diffraction gratings. Write a detailed description of your observations in the appropriate spot in table 1.
3. Repeat steps 1 and 2 with the other LEDs.
4. Compare the spectra of the colored LEDs with that of the white LED. You can illuminate up to four LEDs at one time to help with this step.

The Spectroscope

1. Remove and discard the top from the 35 mm film canister.
2. With a sharp knife, carefully cut a single straight slit across the bottom of the canister. There is probably a thick depression in the very center of the bottom. Avoid cutting through the thick part. Your slit will be easier to make, and it will work better.
3. Hold the container to your eye. You should be able to see light through it. If necessary, pass the knife through the slit again to widen it.
4. Next, tightly roll a tube of black construction paper around the canister and use a bit of tape to hold it together. See Fig. 2.

Figure 2



5. The holographic diffraction grating is the final part of the spectroscope. Hold the grating over the end of the tube opposite the slit.
6. Now you are ready to look at the spectrum of a fluorescent light. Get as close to the light as you can and aim the slit at it. Adjust your position so the slit is brightly illuminated by the light.
7. Look through the holographic grating and down the tube towards the slit at the end. Look to either side of the slit and you will see a surprising spectrum.

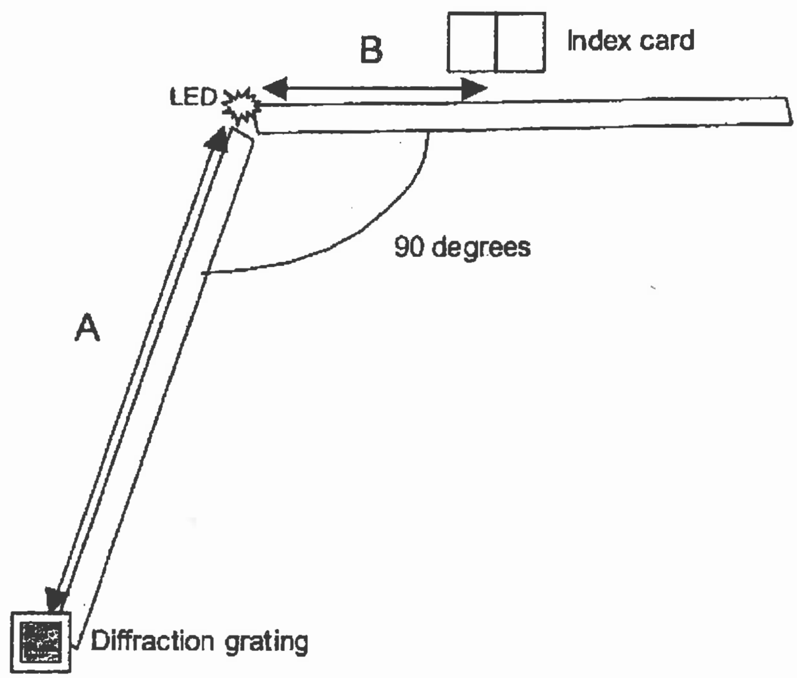
8. Describe the spectrum that you see. Ignore any horizontal dark lines. They simply mean that the slit is not exactly the same width from top to bottom. With the grating rotated to the standard position, you should see a good continuous spectrum over most of the visible range.

   The spectrum comes from the coating on the fluorescent tube and may differ a bit from one type or one manufacturer to another. The real surprise here is to see the few quite bright vertical lines. Each of these is in the shape of the slit. If the slit has an "s" shape to it, so will the bright "line." This is why the slit must be narrow and straight. The bright lines are just a few of perhaps hundreds of lines in the characteristic spectrum for the element mercury. The electrical discharge takes place in the mercury vapor in the tube. A few extra beads of mercury are always running around inside or are stuck to some part of the tube on the inside to make sure there is always enough vapor. Because mercury presents a serious health hazard, disposal of used fluorescent tubes must be handled properly.

Additional Investigations

Measure the Wavelength of Light.

Figure 3



1. Build a simple spectrometer by setting two meter sticks at right angles to each other. Use a protractor to verify the alignment. See Fig. 3.
2. Remove the LEDs and resistors from the component mount.
3. Create a circuit for an LED using the connection method described earlier.
4. Position the LED at the point where the two sticks meet.
5. Place the slide-mounted holographic grating at the end of one meter stick.
6. Draw a straight line across the width of the index card.
7. Turn on the LED by completing the circuit and look at the LED through the grating.
8. Look slightly to the side of the LED and you will see a smeared image of the LED.
9. Move the index card so that the line on the card matches the position of the brightest part of the LED's image.

10. Read and record the distance from the LED to the line on the index card. This will be the value for B in the equation discussed in the introduction.
11. Repeat these steps for each of the five LEDs.
12. Calculate the wavelength for each LED.
13. Compare your results with results from other groups.

Results will vary. Some representative wavelengths are:

Color	***Wavelength (nm)***
Red	700
Orange	620
Yellow	575
Green	500
Blue	430

Analysis

Table 1

LED Spectra

LED Color	Description	Compared to White
White		
Red		
Orange		
Yellow		
Green		

Describe the spectrum that you see when looking through your spectroscope.

Table 2
Wavelength of Light

LED Color	B	λ
White		
Red		
Orange		
Yellow		
Green		

Notes: