Color and Spectrum Discovery Bundle

P2-9575

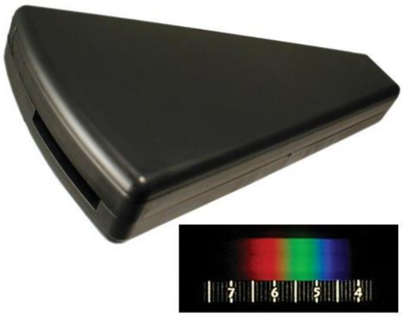
Contents

Primary and Secondary Color Sheets

Rainbow Glasses

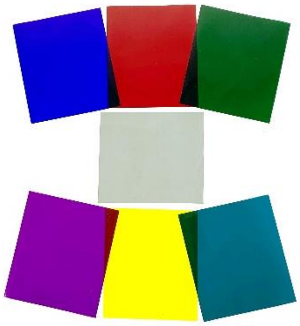
Color Mixing Projector

Color Filter Swatch Book



Quantitative Spectroscope

Spectrum Demo Kit



Color Filters Set

Item	Topic	Instructions
Primary and Secondary Color Sheets (33-0175)	Color of objects Color absorption & reflection	View each of the color sheets through each of the filters from the Color Filters Kit (or illuminate them with colored light). Discuss which colored objects reflect or absorb which colors of light. For example, a yellow object reflects red and green light and absorbs blue, so it would appear red in red light, green in green light and dark (or black) in blue light. How would it appear in magenta light? (Red. It would reflect the red and absorb the blue.)
20 pairs of Rainbow Glasses (P3-6300)	Diffraction of light Spectra from light sources	Each lens of the Rainbow Glasses is a double-axis diffraction grating that will disperse light into horizontal and vertical spectra. Let students view different light sources and discuss the spectra they see. Look at incandescent and fluorescent sources, as well as atomic spectra from mercury lights and neon bulbs.
Color Mixing Projector (P2-9555)	Primary Color Addition	Instructional Guide Included
Color Filter Paddle Set (33-0180)	Spectrum and wavelength Color of objects Absorption and transmission	Use the Primary Mixing Colors Red, Blue & Green, and the Secondary Colors Cyan, Yellow & Magenta for experiments involving additive and subtractive color, color mixing, color transmission, absorption, and filtering of different wavelengths of light. View and analyze spectra from different light sources and gas tubes using the Diffraction Gratings (13,500 Line / Inch Double Axis & 500 Line / mm Single Axis). Students can explore birefringence, light scattering, light reflection, Brewster's angle, how polarized sunglasses work and more using the Polarized and Diffusing Filters
Spectrum Demo Kit (33-0200)	White light spectrum Color subtraction Color and wavelength	Instructional Guide Included
Color Filters Set of 7, 175 mm x 200 mm (33-0195)	Primary and secondary colors Color subtraction Color addition	Instructional Guide Included
Quantitative Spectroscope (P2-7061)	Spectra from light sources and wavelength	An easy way to see and measure light and color from different sources. A built-in scale measures light from 400 nm to 700 nm with a precision of +/- 5 nm. Instructional Guide included.

Related Products

Light Box and Optical Set 2.0 (P2-9580) This affordable Light Box and Optical Set makes it easy to perform experiments involving the optics of lenses, mirrors, and prisms, as well as providing a versatile way to display primary and secondary colors; and both additive and subtractive color mixing.

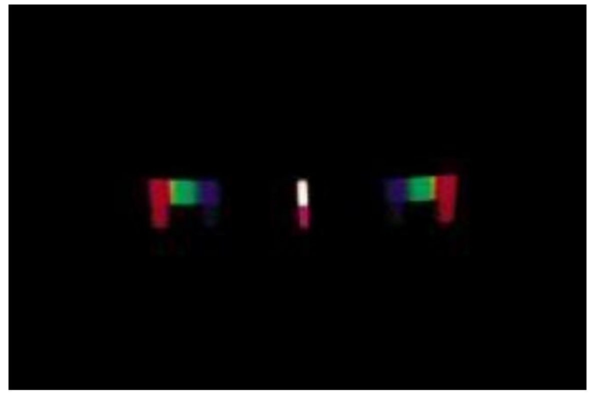
Spectrum Demonstration Kit

33-0200

INSTRUCTIONAL GUIDE

Contents

- Narrow slit mask
- Slit/Anti-slit mask
- Diffraction Grating Mount
- Six color filter cards with spectrum graphs
- Six 1” x 1.5” color filters



Required for activities:

- Overhead Projector
- Sheets of paper, black if possible
- Large sheets of white paper
- Marker

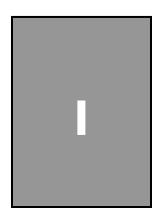
Introduction

Each color filter card is accompanied by a transmission graph showing what percent of each wavelength is allowed to pass through the filter. Humans can see light wavelengths between about 400 and 700 nanometers. Shorter wavelengths (near 400 nm) appear as blue light, and longer (700 nm) wavelengths appear to be red. Wavelengths shorter than 400 nm and longer than 700 nm are referred to as ultraviolet and infrared, respectively.

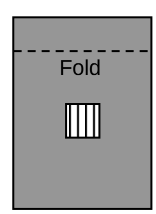
A red filter allows mostly long wavelengths (red and infrared) to pass through, and blocks the short (blue, green, and ultraviolet) wavelengths. Examine the graph for the green filter. It allows 500-550 nm wavelengths to pass through. The blue filter allows 400-500 nm wavelengths to pass through. Look now at the Cyan filter. Cyan is a color that contains both blue and green. The spectrum graph confirms this, showing that wavelengths from 400-550 nm are transmitted.

Examine the graph for Magenta. Can you tell, just by looking at the other graphs, what colors combine to form Magenta? It transmits wavelengths below 500 and above 600 nm. Wavelengths below 500 nm are blue, and those above 600 nm are red. Red and blue combine to form Magenta.

Set-Up



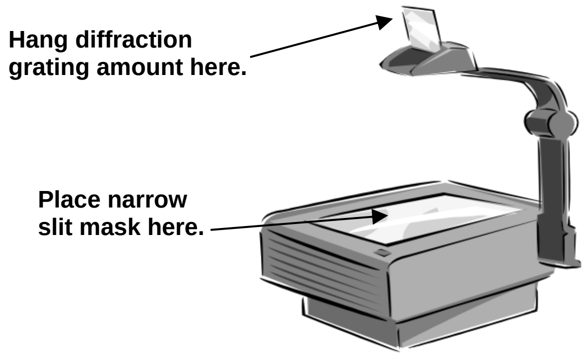
Narrow slit



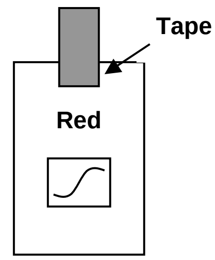
Diffraction Grating Mount

1. Place the narrow-slit mask on the overhead projector stage. Cover the remaining lighted area with sheets of black paper, so that only a narrow slit of light is projected.
2. Hold the diffraction grating mount in front of the projector lens, so that the light passes through the diffraction grating LAST before it travels to the screen. Adjust the position of the grating so that the brightest part of the light beam is centered on it and bright spectra are projected on the wall to the left and right of the slit of light.
3. Fold the diffraction grating mount so that it will hang over the projector lens in

this position. You may need to affix the mount with tape to get it to stay in place.



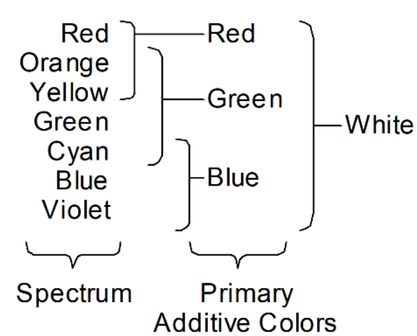
4. Check your setup with the diagram above. You should see, when the room is darkened, a vertical white strip of light with bright spectra to the left and right.
5. Prepare each color filter card by taping the appropriate color filter in the area indicated, as shown. The filter should overhang the card by at least one inch. (Note: Magenta is a bright pink color, and Cyan is a light blue-green.)



Demonstrations

Demo #1: Primary Colors

1. Set up the projector as described in “Setup” so that a bright spectrum is projected on each side of the central white slit.
2. Explain the setup to the students: The diffraction grating separates the white light into a spectrum. (It acts something like a prism, but works in a very different way.) Each different color (wavelength) of light is deflected at a different angle so we can see all of the colors that make up white light.
3. Ask the students to identify the colors they see in the spectrum. (Don’t let them merely recite the colors of the rainbow. Ask them to point out the colors they identify.) They will probably identify red, orange, yellow, green, and blue. They may recognize blue-green (cyan), but if they say that they see purple or violet, ask them to show it to you!
4. List these colors on the board.
5. Place a large sheet of white paper on the wall where one of the spectra is projected. Make sure that all of the colors are on the paper.
6. Cover half of the slit on the overhead stage with the red filter. Ask students to observe the spectrum. Where does the red light appear, compared to the red part of the spectrum? (It appears directly below the red part of the spectrum. They may also notice that, below the orange/yellow part of the spectrum, there is now some red.)
7. Mark and label on the paper the region where the red light is projected.
8. Remove the red filter, and repeat steps 6-7 with the blue filter.
9. Remove the blue filter, and repeat steps 6-7 with the green filter.



10. Remove all filters, and look at the regions covered by the three colors. Together, they should cover the entire spectrum. They should also overlap. Refer to the figure on the right.

11. From this, your students should be able to deduce that red, blue, and green combine to produce white light. They are called the Primary Additive Colors.

12. Summary: The primary colors of light are red, blue, and green. These three colors occupy ranges that, together, make up the entire spectrum. The color filters allow one primary color to pass through and absorb the other two.

Demo #2: Secondary Colors

1. You should do **Demo #1: Primary Colors** before proceeding.
2. Set up the projector as described in “Setup” so that a bright spectrum is projected on each side of the central white slit.
3. Remind students what they observed about Red, Blue, and Green.
4. Cover half of the slit on the overhead stage with the yellow filter. Ask students to observe the spectrum. What colors appear when yellow is split into a spectrum? (Red, orange, yellow, green.) What primary colors occupy this range of the spectrum? (Red, green.)
5. Repeat step 4 with the Cyan filter. Cyan is composed of the primary colors blue and green.
6. Repeat step 4 with the Magenta filter. Magenta is composed of the primary colors red and blue. Why doesn’t this color appear in the spectrum, like yellow and cyan do? (Blue and red are at opposite ends of the spectrum and do not overlap, so magenta is not seen in the spectrum.)
7. Summary: The secondary colors (yellow, cyan, and magenta) are each composed of two primary colors. The filters allow those two colors to pass through, and absorb the other one.

Demo #2a: Color Subtraction

Student understanding of the secondary colors can be strengthened through the following demonstration on color subtraction.

1. Set up the projector as described in “Setup” so that a bright spectrum is projected on each side of the central white slit.
2. Cover half of the slit with the yellow filter. Which primary color is NOT passing through this filter? (Blue)
3. Cover the other half of the slit with the cyan filter. Which primary color is NOT passing through this filter? (Red)
4. Overlap the yellow and cyan filters. What color do you observe? (Green)
5. Ask students to explain this result. (Together, the filters absorb blue and red, leaving only green to pass through and be seen on the screen.)
6. Repeat steps 2-5 with yellow and magenta. (Only red passes through both.)
7. Repeat steps 2-5 with magenta and cyan. (Only blue passes through both.)
8. This process is called color subtraction because each filter subtracts one of the primary colors from light that passes through it. Yellow, cyan, and magenta are sometimes called the Primary Subtractive Colors, because each subtracts one of the Primary Additive Colors from white light.

Demo #3: Complementary Colors

1. You should do Demo #2: Secondary Colors before proceeding.
2. Set up the projector as described in “Setup” so that a bright spectrum is projected on each side of the central white slit.
3. Remind students what they observed about the primary and secondary colors.
4. Cover half of the slit with the red filter and the other half with the cyan filter.
5. Ask students to observe the parts of the spectrum that are passed through each filter. (The two filters allow completely different parts of the spectrum to pass, without any overlap.)
6. Ask students to explain their observations, based on their knowledge of the colors. (The red filter allows only red to pass, and the cyan filter allows blue and green to pass. The two spectra do not overlap. These two colors would add together to produce white light.)
7. Ask students to predict two other pairs of complementary colors (colors that add to produce white light). Confirm their predictions by placing the filters on the slit and observing that the partial spectra do not overlap. (The other pairs are green/magenta and blue/yellow.)

Demo #3a: “Complementary Spectrum”

Slit-antislit Mask

1. You should do Demo #3: Complementary Colors before proceeding.
2. Set up the projector as described in “Setup” so that a bright spectrum is projected on each side of the central white slit.
3. Replace the single slit mask with the “slit-antislit” mask. You may have to remove any additional black paper that you placed on the projector stage.
4. You should observe a similar spectrum on either side of the central white slit to that observed before.
5. Ask students to look in the area directly below the spectrum. In that area, there should be another spectrum that is composed of different colors. Ask students to identify the colors they see in the new spectrum. (Cyan, magenta, yellow)
6. Ask students to relate the position of these colors to the positions of the primary colors in the normal spectrum. (The colors’ complements appear directly below: cyan below red, magenta below green, yellow below blue.)
7. The special “slit-antislit” mask allows this “complementary spectrum” to form. The normal spectrum is formed when a narrow slit of white light is split into colors. The “complementary spectrum” is formed when a shadow is spread out in an area of white light. The diffraction grating separates white light into different wavelengths. The slit of light allows the wavelengths to be separated and appear individually on the screen. The “antislit” allows individual wavelengths to be subtracted from the light being projected on the screen. For example, when red light is subtracted from white, the result is cyan.

Related Products

Light Box & Optical Set 2.0 (P2-9580) This affordable Light Box and Optical Set makes it easy to perform experiments involving the optics of lenses, mirrors, and prisms, as well as providing a versatile way to display primary and secondary colors; and both additive and subtractive color mixing.

Subtractive Color Theory Demonstration (P2-9565) The Subtractive Color Theory Demonstration provides students with a hands-on experience as they learn subtractive color mixing and explore color theory in a

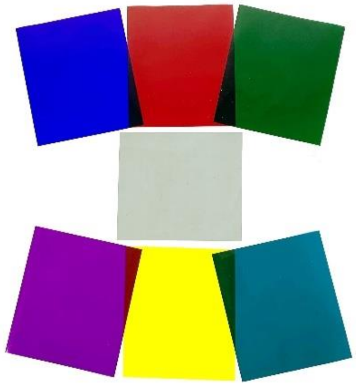
Color Filter Set of 7, 175 mm x 200 mm

33-0195

INSTRUCTIONAL GUIDE

Contents

Your kit includes six color filters and one neutral density filter cut into 175 x 200 mm sheets.



Filters Include:

- Blue
- Magenta
- Red
- Yellow
- Green
- Cyan
- Neutral Density (50% transmission)

Background

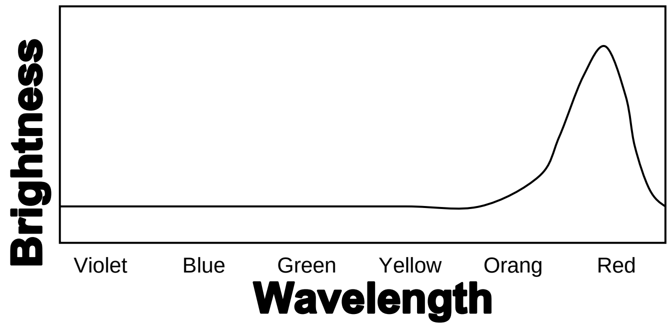
> *"To the physicist, the colors of things are not in the substances of the things themselves. Color is in the eye of the beholder and is provoked by the frequencies of light emitted or reflected by things. We see red in a rose when light of certain frequencies reaches our eyes. Other frequencies will provoke the sensation of other colors. Whether or not these frequencies of light are perceived as colors depends on the eye-brain system."* (Hewitt, 411)

The above quote illustrates two points: (1) color is a subjective excitement in the eye that tells the brain what frequency of light is hitting it. The eye is only sensitive to a narrow band of frequencies known as visible light. And, if the eye or brain receives more than one frequency at a time, they will often interpret this as only one color. (2) We perceive an object's color to be our eye/brain response to the light that is either created or reflected. Reflected light can have its spectrum changed by the object it reflects off of because most materials absorb some frequencies and reflect the rest. If an object absorbs most visible frequencies and reflects red, for example, the material appears red. If a material reflects all of the light shined on it, it will have the same color as the initial light source. If it absorbs all light, it will appear black.

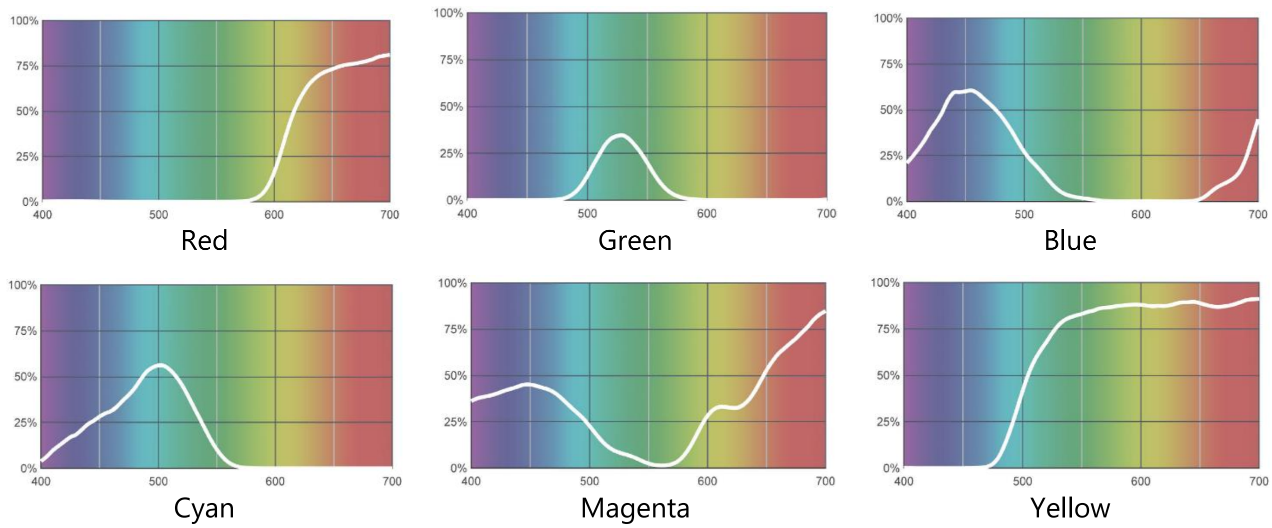
Introduction

The color of a transparent object depends on the color of the light it transmits. A red piece of glass appears red because it absorbs all the colors that compose white light, except red, which it transmits. The material in the glass that selectively absorbs colored light is known as a pigment. (Hewitt, 414) The transmittance of an object can be shown with a wavelength spectrum graph.

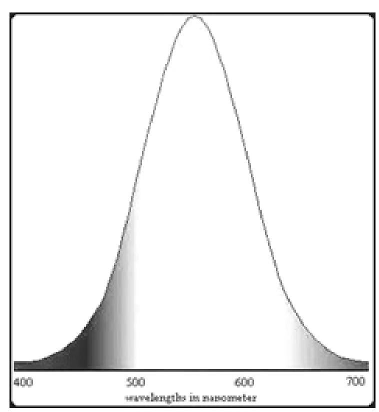
Such a graph shows the amplitude, or brightness, of the light of each wavelength that is transmitted. So, the wavelength spectrum of a red plate of glass might look something like below...



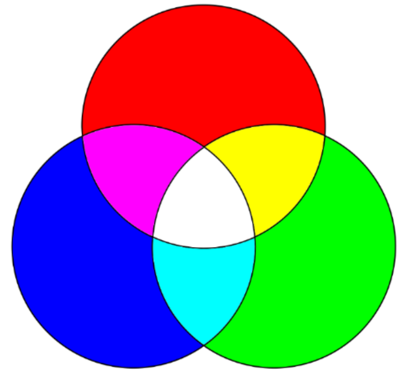
Notice that the transmitted light is brightest near the red part of the spectrum. The rest of the wavelengths have low brightness. Here are the transmittance spectrums of the 6 color filters included in the kit. They refer to wavelength in nanometers along the x-axis. Rather than using brightness or amplitude, the graphs refer to the transmission, or the percentage of the original brightness that was allowed to pass through, along the y-axis.



Notice that there aren't pure peaks at red, blue, green, etc. Rather, what our eyes perceive as color is often made up of several different frequencies. All of the filters let in high wavelength light, but our eyes are only sensitive to up to about 700 nm. The graph to the right shows the relative eye sensitivity of a *standard observer.* Notice that humans are more sensitive to green and yellow light than any other. A conjecture can be made by pointing out that humans evolved in a natural setting of green foliage. Sensitivity to green was much more important than sensitivity to red or blue. This relative sensitivity plays a big part in how we perceive colors. So not only does our eye-brain mechanism assign single colors to light made up of multiple wavelengths, but it is more sensitive to some of those wavelengths than it is others. All of this adds up to a very confusing time for scientists and artists.



Activities



1. Use several projectors as light sources to shine colored light onto a screen or white wall. Arrange the projectors to overlap each other and create complementary colors by adding a primary with its complement. Can your students explain this with the help of the chart? (yellow = red + green, so blue + yellow = blue + red + green = white)
2. Subtract color from the projector light source by placing one, then two, and then three filters in front of the source. Use three secondary colors first.
3. Try shining colored light onto colored objects, like sheets of construction paper or student art. Very powerful demonstrations consist of images with definitive colors that everyone is familiar with (i.e., red hearts with piercing black arrows, green money.) Keep the real color of the image or paper secret by only showing it in the colored light. Have your students try to figure out what color it really is. Or, by knowing what color the sheet is, have them try to guess what color light is shining on it. If you really want to freak them out, try eating food like fruit and vegetables bathed in colored light. Does it have an effect on the taste!
4. Have your students put on diffraction grating glasses (see Rainbow Glasses below). View a light bulb with them on (lower wattage, diffuse bulbs work best so that students don't focus on the very bright center of the light.) While they are analyzing the spectrum given off by the bulb, hold a color filter in front of it. They should see sections of the spectrum simply disappear. Compare the colors left over to the transmission charts.

Related Products

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Subtractive Color Theory Demonstration (P2-9565) The Subtractive Color Theory Demonstration provides students with a hands-on experience as they learn subtractive color mixing and explore color theory in a whole new way.

Bibliography

Conceptual Physics: The High School Physics Program. Paul G. Hewitt. Pearson Education, Inc.

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Quantitative Spectroscope

P2-7061

INSTRUCTIONAL GUIDE

Contents

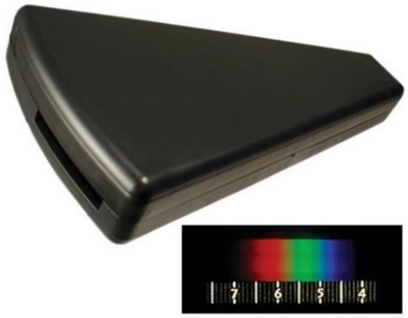
- Quantitative Spectroscope

Recommended for Activities:

- **NexGen Spectrum Tube Classroom Bundle (P2-9902)**

    OR

- **Spectrum Analysis Classroom Bundle (P2-9502)**



Background

At some point, you may have noticed a rainbow projected onto a table or wall from the rim of a glass or crystal that was placed in the sun. Where did these colors come from? Why were they always in the same order with red on one side and blue on the other? At a time when it was commonly believed that light was made up of tiny particles called corpuscles, Christian Huygens (1629-1695) made a conceptual leap and described the behavior of the reflection and refraction of light with the same models that described the behavior of waves in water. As years passed, other great scientists such as Augustin Fresnel (the Fresnel lens) and Thomas Young (1773-1829) contributed experimental evidence to support the wave theory of light. Young's experiments, particularly those dealing with the diffraction of light conclusively demonstrated that light must travel in waves.

This conceptual model of light worked well until scientists tried to explain spectra made by burning chemical salts in a flame. These spectra did not stretch continuously from red to blue as the spectra of ordinary daylight does, but had several bright lines and many large dark spaces in between. Light would again be viewed as a particle when, in 1921, A.H. Compton demonstrated that light possessed *momentum*, a very particle-like quality.

Today, our current theory of light embraces both wave and particle aspects. Light is an electromagnetic wave that travels in small particle-like packets called photons. Each photon travels at the same speed: 3×10^8 m/sec, the speed of light. The energy of a photon is directly proportional to its frequency. The higher the frequency, the more energy it contains. We are all familiar with ROY G. BIV. The letters stand for the colors in the rainbow with Red, Orange, Yellow, Green, Blue, Indigo, and Violet. These colors are listed in order of increasing energy (decreasing wavelength) and comprise our visible spectrum. But the electromagnetic spectrum doesn't stop at visible light! It continues beyond the visible into higher energies with ultra violet, x-rays, and gamma rays. It also extends below red into lower energies with infra-red, and radio waves.

Electromagnetic radiation (in our specific case, light) is created when an electron moves from a higher energy level (electron orbit) to a lower energy level. The photon of light that is emitted has an energy that corresponds exactly to the difference in energy between the two orbits.

Introduction

The heart of the spectroscope is the diffraction grating. This thin plastic film has thousands of very closely spaced lines etched in its surface—in our particular case, 500 lines per cm. This grating bends light as it passes through the lines etched on its surface according to the principles of diffraction. Additive and destructive interference between the light waves diffracted by the grating develop the spectrum seen with the spectroscope. Since the amount of diffraction is dependent on wavelength, we can quantify the wavelengths being emitted from a light source by the amount the light is diffracted. The numbered scale should be to the left of the slit as you look through the eyepiece. Each number on the scale indicates the wavelength of light in nanometer (nm) when multiplied by 100 (1 nm equals 1×10^{-9} meters).

Several types of spectra can be viewed with the Quantitative Spectroscope:

Continuous Spectra are usually produced by a luminous liquid or solid, such as the glowing filament of a lamp. The intensity of different wavelengths may vary so some colors may appear brighter than others.

Emission Spectra are produced by photons emitted from an excited element or compound (such as a gas spectrum tube) as it moves from a high energy level to a low energy level. The spectrum produced by this method is unique to each element and can be used to identify unknown matter.

Absorption Spectra are generated by passing a continuous spectrum (white light) through a cooler gas located between the light source and the observer. The cooler gas absorbs the wavelengths it would normally *emit* if it were the energized source, so dark lines will appear in the continuous spectrum. This can be thought of as the inverse of an emission spectrum.

Activities

Hold the spectroscope so the small end with the square hole is toward you. The wider, curved end has a narrow slit (which lets light into the spectroscope) and a wide window with a numbered scale. While holding the spectroscope a few inches in front of your eye, look through the eyepiece of your spectroscope and point the slit end at an incandescent light bulb.

The Quantitative Spectroscope is a great tool to use for open-ended light and color activities. First try looking at a fluorescent light bulb with your spectroscope. Now, instead of a smooth continuous spectrum you see several bright lines. One is violet, one is cyan (light blue-green), one is green, one is yellow, one is orange, and a couple of red lines. This spectrum is primarily produced by mercury vapor. Try looking at other types of lamps, such as neon, or sodium vapor lamps. How do these compare? Can you identify the gases inside each light source? Compare other light sources if you can, such as halogen lamps, gas lanterns, headlights, LEDs, neon signs, etc. Great sources for interesting spectra are the halide lamps commonly found in gymnasiums. Can you tell which lamps use solid filaments by looking at their spectra?

Wavelengths for "brighter" spectral lines for some elements are given:

Element	Wavelength (nm)
Hydrogen (H)	434, 486, 656
Mercury (Hg)	436, 546, 577, 579
Helium (He)	447, 471, 492, 502, 588, 668
Sodium (Na)	589, 590

Note that in many cases closely-spaced spectral lines may not be resolvable with this spectroscope and wavelength data is given for reference only.

Sodium is very common and very bright and may be present in many flame spectra as a trace of contamination. A classic light and color activity is identifying unknown white salts by observing their color when ignited in a flame. These salts can be introduced into a flame by dipping a moist wire into the chemical salt then bringing the salt-coated wire to the base of the Bunsen burner flame. The flame will begin to burn with a color characteristic of the salt used.

Other bright line spectra can be produced by burning salts of various chemicals in a gas (Bunsen burner) flame. Some common elements are:

Element	Wavelength (nm)	Color
Copper (Cu)	530	Green/Blue
Sodium (Na)	589	Yellow
Strontium (Sr)	606	Orange
Lithium (Li)	670	Red

Spectrum tubes contain a range of gases and are a great resource to observe the emission spectra of many different gases. When they are energized, the gases glow and emit photons of unique wavelengths making for another great unknown identification activity with the Quantitative Spectroscope. For example, helium and hydrogen are both light gases at the top of the periodic table, but helium has one more electron than hydrogen. Helium will have a more complex emission spectrum compared to hydrogen due to its extra electron.

Resources

Project Star Spectrometer (P2-7055) Explore flame spectra, streetlights and solar spectra with this dependable device. Since it is labeled in electron volts and nanometers, you can use it in both your physics and chemistry labs.

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.

Spectrum Tube Carousel Classroom Bundle (P2-9902) A classic atomic theory demonstration! Energize the gas and view the characteristic atomic spectral lines with any spectroscope. This complete set comes with 8 different gas Spectrum tubes. Spectroscopy Tube length is approx. 26 cm.

Color Mixing Projector

P2-9555

INSTRUCTIONAL GUIDE

Contents

- Color Mixing Projector
- Power Supply
- Instructional Guide

Recommended for Activities:

- Construction Paper
- Food coloring

Introduction

The spectrum of visible light consists of a broad swatch of wavelengths and frequencies along the electromagnetic spectrum. On the other hand, our perception of light is not based on a continuum so much as it is the result of the mixing of only a few colors that represent a much narrower selection of light wavelengths. Indeed, this color mixing is a bit more complex than the traditional color wheel that historically (and incorrectly) identifies red, yellow, and blue as the primary colors that mix to create orange, green, and purple.

The compact size and elegant simplicity of the Color Mixing Projector makes exploring and experimenting with additive color mixing accessible for everyone. Use a white sheet of paper as a small screen for individual or small group work, or project onto a white wall or larger screen to demonstrate concepts for the entire class. Address physics concepts such as wavelengths and the electromagnetic spectrum and connect the learning to concepts in biology such as sensory perception, anatomy and physiology of the eye and nervous system, and variation between individuals and species.

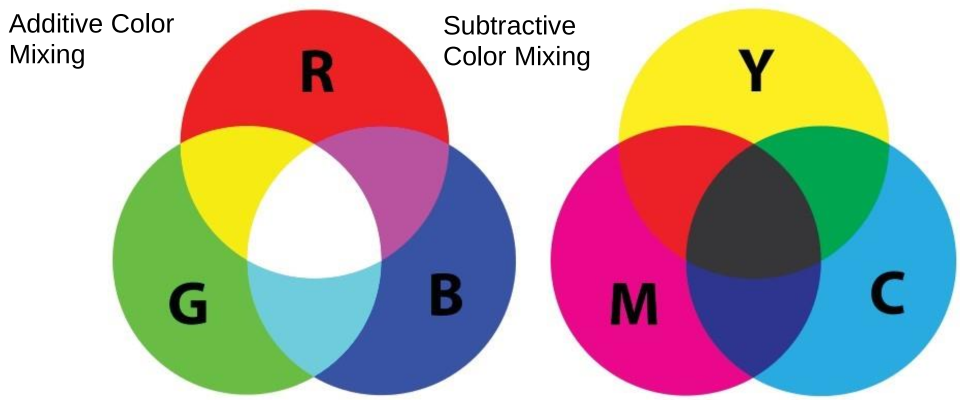
Background

The human nervous system senses light as it hits the retina at the back of eye. The retina is made up of light receptor cells (photoreceptors) called rods and cones. Rods do not recognize colors and send messages to the brain regarding shape, lines, light, and shadows. Cones are capable of distinguishing colored light. There are three kinds of cones. Each is activated by a narrow range of light wavelengths in either the red, green, or blue range. Different colors along the visible light spectrum activate the different cones in varying amounts sending combinations of messages to the brain such that humans can detect and distinguish between a very broad range and variety of colors.

The Color Mixing Projector models the properties of additive color mixing that can be detected by the human eye. By mixing the three primary colors of red, green, and blue light, the projector can be used to create cyan light (green and blue), magenta light (blue and red), yellow light (red and green) and white light (red, green, and blue). By varying the intensity of each of the light sources, a broad range of

additional colors can be created.
This particular Color Mixing Projector works well in conjunction with the human eye, because it uses the primary colors that activate cone photoreceptors. Other species, with different combinations of photoreceptors, would recognize the broadest mixing of colors with lights that matched their own photoreceptors. For example, some insect species would recognize additional color combinations if an ultraviolet light source was added.

Mixing different colors of light is known as additive color mixing. In contrast, subtractive color mixing creates different colors when additional colors of the spectrum are subtracted or absorbed by a medium, allowing a limited range of light to reflect off of the medium. The light that is reflected is the color detected by the eye. Primary colors for subtractive color mixing are cyan, magenta, and yellow. With the addition of black—or key—the CYMK color model is typically used for inks, paints and printing, including photographic printing.



Set-Up

For younger students, focus on science practice skills such as predicting, making observations, and explaining at an age-appropriate level. More complex physics, anatomy, and physiological concepts can be addressed using the same activities with middle school students and higher.

Use a sheet of white paper as a small screen for small groups or a larger screen or white wall for classroom demos. Dimming the lights is advised.

Getting Started:
To begin color mixing exploration, allow students to see the colors on their own before overlapping the beams of light on the screen. Then demonstrate what happens when two colors are combined. Be sure to explore all three combinations of two colors. Use the knobs to adjust the intensity of each color LED such that the Projector projects white light. Play a little with the intensity of the LEDs to create different mixtures. Have students share their observations and any explanations for what they observe. Introduce terms such as primary colors, secondary colors, and complementary colors.

Shadows:
Adjust the intensity of the LEDs to create a white light. Use a pencil or other narrow object to create a shadow on the screen. Vary the distance of the pencil from the screen. Have students share their observations and any explanations. You may also choose to turn off one color beam at a time and make observations of the shadows with only two colors of lights. Have students discuss the explanations for their observations.

Activities

Have students explore color perception and light by experimenting and playing with additional concepts. Be sure to discuss observations and possible explanations.

- **Color Absorption:** Project the colored light beams onto different colors of construction paper or butcher paper.
- **Color Absorption II:** Project the colored beams through different colors of plastic filters to a white screen behind.
- **Pinhole:** Project the lights through a hole in a piece of paper. Vary the distance of the hole from the light sources and the screen. Pay attention to the positions of the colors on the screen. Which one is on top? Bottom? Right? Left? Can the students explain their observations?
- **Color Fatigue/After Images:** Choose just one of the LEDs to turn on. Stare at the center of the white patch for 30-60 seconds. Be sure not to look away from the light! Turn off the light beam and continue looking at the screen. What do you see? Try it with another primary color. Then try again with a secondary color (a mix of two LEDs). What do you think would eventually happen to your vision if you were exposed to an environment with only blue light? Green? Red?
- **Subtractive Color Mixing:** Use ink, paint, or food coloring (or other liquids with pigments that selectively absorb different wavelengths of visible light) to experiment with subtractive color mixing. Compare the results to additive color mixing with colored lights.

NGS Standards

Students who demonstrate understanding can:
1-PS4-2: Make observations to construct an evidence-based account that objects can be seen only when illuminated.
1-PS4-3: Plan and conduct an investigation to determine the effect of placing objects made with different materials in the path of a beam of light.
4-PS3-2: Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
4-PS4-2: Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.
4-LS1-2: Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.
MS-PS4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
MS-LS1-8: Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

Related Products

Light Box and Optical Set 2.0 (P2-9580) This affordable Light Box and Optical Set makes it easy to perform experiments involving the optics of lenses, mirrors, and prisms, as well as providing a versatile way to display primary and secondary colors; and both additive and subtractive color mixing.

Subtractive Color Theory Demonstration (P2-9565) Students manipulate transparent tiles on a back-lit board to see how color mixing with light produces different results than mixing pigments.