MODULE m4

Light and Colors

INTRODUCTION

Module 4, Light and Colors, encompasses three activities that help students explore, investigate and understand the relationships between visible light and color. Visible light as a form of energy is addressed in Activity 10.

Activity 8: Light, Prisms, and the Rainbow Connection
Activity 9: Investigating the World of Colors
Activity 10: Using Centers to Investigate Special Properties of Light

In Activity 8, students use prisms to separate visible light into its component colors. Using Activity 9 students study the primary colors of pigments and use a color wheel to help them understand the relationship between the primary colors and secondary colors. Students will also do an experiment to discover how their eyes see color. Activity 10, Discovery Centers, provides you with an outline of 6 different classroom centers to help students learn about the special properties of light, including visible light as a form of energy.

The following interactive web-based tutorials can be used to enhance this module, explain difficult concepts, and enrich the classroom experience: Newton's Prism Experiments, Light and Color, Moire Images, Optical Illusions, Color Separation, and Polarization of Light, http://micro.magnet.fsu.edu/optics/tutorials/index.html

Activity 8

Light, Prisms and the Rainbow Connection

White light is made up of all the visible colors in the electromagnetic spectrum. It is possible to separate the colors of white light with a prism. As light passes through a prism, its speed changes and it is bent, or refracted. Because of the angles and plane faces of the prism, each frequency of light is refracted by a different amount. Violet has the highest frequency and is refracted the most. Red has the lowest frequency and is refracted the least. Because each color is refracted a different amount, each bends at a different angle resulting in a fanning out and separation of white light into the colors of the spectrum.

The color spectrum is actually a continuum of color from red to violet, but the following colors are conventionally identified in the order that they appear: red, orange, yellow, green, blue, indigo, and violet. A way to remember the order of the colors of the spectrum is with the mnemonic name: ROY G. BIV.

How are rainbows made? Water droplets in the air can act like prisms and separate the colors of sunlight producing a spectrum known as a rainbow. To see a rainbow, you have to be standing with the sun behind you. The sunlight shines into water droplets in the air, bending as it moves from the air into the water, reflecting off the sides the drops, and bending again as it exists the drops separating the sunlight into the colors of the spectrum.

In this activity, students will observe white light passing through a prism and separating into the color spectrum. They will also make the connection between light passing through a prism and how rainbows are formed. As with the other activities, how much time you spend on this activity is up to you. However, it is recommended that you complete the activity in stages. The topic “rainbows” can be the basis for an entire unit of study if you use this activity and the accompanying extensions as a jumping off point.

Materials:

- ☐ Prism
- ☐ Flashlight
- ☐ White paper
- ☐ Science Notebook
- ☐ Transparency of visible spectrum

What will the students do?

As an introduction to this Activity, read the Historical Vignette aloud to students while they explore the prisms. Students will be attempting to "make a rainbow" by producing the spectrum using a flashlight, prism, and white paper. Encourage students to explore the prisms and articulate some ideas about rainbows and how they form.

1. Students working in pairs or in small groups predict how to best make a rainbow using the materials from the *Science, Optics and You* package. Darken the classroom as much as possible. The most brilliant spectrums are produced when the room is very dark and the flashlights very bright.
2. Students will compare the rainbows that they produce with other groups of students and identify the colors that they see in their Science Notebooks. This is a good time to introduce the term color spectrum to help students describe what they see. Have students compare their earlier predictions with what they observe.
3. Students write about their observations and draw diagrams in their Science Notebooks. Drawings should show how a prism separates the colors of light.

More Prism and Rainbow Demonstrations

Depending on the amount of light in the classroom and the intensity of the flashlights, students will have varying degrees of success in projecting color spectrums. The following are alternative methods to demonstrate the separation of white light into the color spectrum.

- On a bright sunny day, students can go outside and use sunlight through a prism to project a color spectrum on a piece of white paper.

- Cut a slit 1 cm wide and 15 cm long in a piece of black construction paper. Place the paper over the glass of an overhead projector so that just a slit of light is projected in a darkened room. Position a prism close to the projector and within the light beam and allow students to experiment to find the best placement for projecting a color spectrum.

- Students can spray a fine mist of water in bright sunlight to produce a rainbow. This is an excellent rainbow demonstration since, as with natural rainbows, water droplets are used. Or, this can also be done in the classroom using an overhead projector projecting a slit of light. Spray a fine mist in front of the projector across the light beam. A color spectrum can be seen within the mist.

EXTENSIONS:

Writing. Have students write a poem about rainbows with lines for each color of the rainbow: ROY G BIV.

Music. Play recordings of songs about rainbows such as *Somewhere Over the Rainbow* or *The Rainbow Connection*. Have students write their own verses for the songs or make up songs of their own.

Research. Isaac Newton and Rene Descartes discovered much of what we know today about rainbows. Using a variety of print and electronic media, students can research and write about the discoveries of Newton and Descartes. Older children can write stories about Newton and other scientists for younger ones and younger students can write for other classes.

Expository writing. Use the following as an expository writing prompt.

> *We learned that raindrops can be like prisms and make a rainbow in the sky.*
> *Think about how sunlight moves through a raindrop and separates into the color spectrum.*
> *Now write a description of how rainbows are made.*

Narrative writing. Use the following as a narrative writing prompt.

> *We have all heard the myth that at the end of the rainbow you can find a pot of gold. Use your imagination and think of something else that you can find at the end of the rainbow. Now write a story about how you can reach the end of the rainbow and what you will find there.*

Reading. Choose poems (there are 70) from *Rainbows are Made* by Carl Sandburg (ISBN 015265481X) that relate to natural phenomena. Have students react to the poems and then write their own about rainbows, rain, or water.

Water by Ken Robbins (ISBN 0-8050-2257-0) is one of four photographic essays about the elements that combines geography, weather science, photography, optics, and art to learn about water. The beautiful hand-colored photographs combine black and white photography with an artist's interpretation of natural phenomena.

Share with students *A Drop of Water* by Walter Wick (ISBN 0-590-22197-3). Another photographic essay, this investigates the three states in which water is commonly found and its properties in each state.

HISTORICAL VIGNETTE: ISAAC NEWTON

This vignette was written to be read aloud. You may choose to read this *before* completing the activity, allowing students to handle the prisms as you are reading to them about Isaac Newton.

Young Isaac Newton and the Color Spectrum

In 1665, Isaac Newton was a young scientist studying at Cambridge University in England. He was very interested in learning all about light and colors. One bright sunny day, Newton darkened his room and made a hole in his window shutter, allowing just one beam of sunlight to enter the room. He then took a glass prism and placed it in the sunbeam. The result was a spectacular multicolored band of light just like a rainbow.

Newton believed that all the colors he saw were in the sunlight shining into his room. He thought he then should be able to combine the colors and make the light white again. To test this, he placed another prism upside-down in front of the first prism. He was right. The band of colors combined again into white sunlight.

Newton needed to prove that the colors came from the sunlight and not from the prism. Newton placed a card with a hole in it between two prisms allowing only red light from the first prism to go through the second prism. The red light going through the second prism did not split into

different colors, or turn white again; it remained red. Newton repeated this with all the colors with the same result. Newton proved that the colors came from the sunlight and were not in the prism.

Newton was the first to prove that white light is made up all the colors that we can see. Newton wrote about his discoveries in his book, Opticks, in 1704. His book has become one of the most important scientific books ever written. The following is a description of his experiment in his own words:

> *In a very dark chamber, at a round hole, about one-third part of an inch broad, made in the shut of a window, I placed a glass prism, whereby the beam of the Sun's light, which came in that hole, might be refracted upwards toward the opposite wall of the chamber, and there form a colored image of the sun.*

Role Play. After reading aloud the vignette, have students research Newton's experiments and discoveries. Students can then write a skit depicting the day that Newton made his discovery about the properties of sunlight. Students will include imagined dialogue of Newton talking to his friends and family about his discovery.

Writing/Art. Students draw and write a comic book version of the story of Newton's discovery. Each step of Newton's experiment should be depicted in the frames of the comic book. Students then share the comic book with other students and other classes.

ARTIST VIGNETTE: THOMAS MORAN

During the 1800s, painters often joined government expeditions to the western wilderness of America. They painted and brought back to the cities in the east exciting and beautiful paintings of the Rocky Mountains, Yellowstone and Yosemite. In 1871, the painter Thomas Moran joined an expedition to Yellowstone in Wyoming. Yellowstone is now well known for its waterfalls, hot springs, and geysers. Moran painted pictures of the beautiful scenes that he saw. These paintings were reproduced and became very popular. Moran's paintings helped make Americans aware of the natural wonders of the western wilderness. This awareness helped establish Yellowstone as the first national park in 1872. Hot Springs of Yellowstone is one of his paintings and shows a rainbow forming in the mist and steam of a hot spring.

Moran's *Hot Springs of Yellowstone* can be viewed on the Internet. After viewing Moran's painting or other landscapes from the same period discuss with students how pictures can help communicate strong feelings about places.

Writing/Art/Current Issues. Students select a natural or historical location in their neighborhood or city that is at risk or that they feel needs to be preserved. Students then draw and color pictures of the site. They may choose to write letters to send to community leaders to encourage them to support its preservation. Students as a group can also paint a mural of the location. This is an opportunity to let students either choose an activity that they wish to complete or to create their own activity based on Moran or other artist.

Activity 8

Light, Prisms and the Rainbow Connection

Did you know that the light from the sun or from white electric lights is made up of all the colors we can see? In this activity you will use a prism to investigate colors.

You see a rainbow when sunlight shines on raindrops in just the right way. The sunlight is bent as it moves through the drops. It spreads out and is reflected back to us as a colorful rainbow in the sky. The group of colors that we can see with a prism or in a rainbow is called the color spectrum.

Materials:

- ☐ 2 Prisms
- ☐ Flashlight
- ☐ White paper

1. Before you begin, try to guess how you could make a color spectrum with a flashlight, prism, and a piece of white paper. In your Science Notebook, write down (or draw) your ideas about how to make a rainbow and share your ideas with your group.

2. Use your materials to try and make the color spectrum appear on a piece of white paper, like Isaac Newton did. This works best when the room is very dark and the flashlight very bright.

3. Can you identify colors in the spectrum you created?

4. Compare your color spectrum with the spectra other students have made. In your Science Notebook, write how they are alike and how they are different.

5. In your Science Notebook, draw a picture showing the flashlight, prism, paper and the color spectrum.

6. Compare how you made the spectrum appear on a piece of paper with how light moving through raindrops can make a rainbow. In your Science Notebook include a diagram that supports your idea about how a rainbow is made.

7. In your Science Notebook, write down any questions you still have about rainbows and how rainbows are formed. With each question, suggest a way that you could find the answer.

ACTIVITY 9

Investigating the World of Colors

What we notice most about light is color. However, the way we see colors has to do with how light is reflected or absorbed. The reason something appears red is that all of the colors in white light are absorbed except red. The red light is reflected to our eyes and therefore we see the color red. If an object *absorbs* all of the colors found in white light then it appears black. If all of the colors are *reflected* an object appears white.

Color comes from the visible spectrum of light. The colors that make up white light from longest to shortest wavelengths are red, orange, yellow, green, blue, indigo and violet. Scientists measure the wavelength of light in a unit called a nanometer (one billionth of a meter). In any system of colors, those that cannot be mixed from any of the others are called primary colors. The primary colors of *light* are red, green and blue. From these three colors, every other color of light can be made. Televisions, movies, and computer screens all project red, green and blue dots called pixels; these pixels create the variation in shades and images that are formed on the screen.

In the human eye, the retina, which is the inner lining of the eye, is composed of cells known as rods and cones. The rods allow our eyes to pick up small bits of light and are the type of cells that are the most numerous on the retina. Cones are the other kind of cells making up the retina. The cones are responsible for the color and clarity of an object. The heaviest concentration of cones is found in the center part of the retina. For that reason the best color and clarity of an object can be seen when the object is directly in front of the eye. As the object moves more to the side of our eyes, the clarity and the amount of color we can see is diminished. However this side vision or peripheral vision allows us to see the smallest amount of light and motion.

Paint pigments mix differently than light. The type of color mixing familiar to most artists is that done not with lights but with paints or pigments. Each color of paint can be thought of as a filter that removes all of the light frequencies except the one meeting the eye. Red, yellow and blue are the most common ones primary colors of paints. For example, a red paint reflects only the wavelengths that create a sensation of red; the rest are absorbed. Mixing primary pigments with other colors results in darker colors as more of the light energy is absorbed. The absorbed energy becomes heat and that is why, for instance, white cars are cooler than black ones.

SOME OF THE MATERIALS LISTED ARE NOT FOUND IN YOUR OPTICS PACKAGE. CHECK THE LIST CAREFULLY BEFORE YOU BEGIN THE ACTIVITY.

BEFORE YOU BEGIN, MAKE A COPY OF THE COLOR WHEEL, FOUND IN APPENDIX C, FOR EACH STUDENT.

MATERIALS:

- ☐ White unlined paper
- ☐ Science Notebook
- ☐ Water
- ☐ Watercolor paints
- ☐ Paintbrush
- ☐ Container for holding water
- ☐ Blank color wheel (in the Appendix)
- ☐ 3 markers of the same size but different colors

This activity consists of two investigations: the first investigation encourages students to experiment with color vision. In the second investigation, students experiment with mixing primary colors of pigment to produce secondary colors, work with color wheels and explore the effects of combining colors.

WHAT WILL THE STUDENTS DO?

Investigation I

1. Working in pairs, students test their ability to see color peripherally. They will take turns testing one another by using different color markers.
2. Each student will view 3 different objects and record what they experience in their Science Notebooks.

Investigation II

In the second investigation, students will be mixing watercolors. In mixing colored pigments, the three colors that combine in various proportions to give all the other colors of the spectrum are red, yellow, and blue. Because this phenomenon depends on the ability of the pigments to absorb the various wavelengths of white light, red, yellow and blue are called subtractive primary colors.

EXTENSIONS

Art and Nature. Another way of introducing students to the art of color mixing and pigments is to have them produce certain colors by using materials that are found in nature. Students could bring in materials they think will produce a color when rubbed on paper, for example seeds, fruit peels, leaves, berries, soil, and rocks. Students then can use these materials to produce paintings or other art..

History. Have students use the natural materials gathered in "Art and Nature" above to create cave drawings. With a little research about the kinds of drawings that exist in many parts of the world, students can discuss reasons that prehistoric man created art, ways the art was created, and the difference between pictographs and petroglyphs. Students can create their own "caves" complete with artwork. Further research can be done on dating techniques used in the caves as Lascaux, France, for example, or rock paintings in Australia and India.

Reading. Read aloud *The Legend of the Indian Paintbrush* by Tomie dePaola (ISBN 0-698-11360-8). This is a wonderful accompaniment to the "Art and Nature" activity above since it deals with a Plains Indian boy who creates beautiful paintings on animal hide. While he creates colors from natural materials such as berries and flowers, he is unable to mimic the bright and vibrant colors of the sunset.

Mathematics. Depending on the experience of your students, it would be an excellent math extension to have them construct their own blank color wheel by drawing a line across the diameter of the circle, identifying the radii, measuring the angles, and then comparing their color wheels to pie graphs. Materials needed are white paper, a drawing compass, and a protractor.

Narrative writing:

> *Each of us has seen how grass can leave a green stain on clothes.*
>
> *Before you begin writing, think about some materials found in nature that could produce other colors.*
>
> *Now tell a story about how you would go about finding materials to produce paint and create some artwork to produce a record of your trip through the forest.*

Careers. To answer the question, "Why produce a color wheel?" or, "Who uses a color wheel?" have students research careers that involve the use of color. For example, interior designers carry color samples with them as they investigate new and creative ways to combine colors for their clients. Artists combine colors to create certain effects to fool the eye or to represent things in a realistic way. Men and women in the textile industry combine colors in special ways so that certain fabrics reflect light to enhance the color combinations. Students could choose a career or a technique used in one of the careers, investigate how colors are used, and present their findings to the class.

HISTORICAL VIGNETTE: THE HISTORY OF TEMPERA PAINTING

Painting as an art medium has a tradition that extends far back into prehistory. It was used to show images, religious symbols, and to record events about every day life. Many of the works of art that still survive from the Stone Age were painted on the walls of caves in Spain and France. Most of these paintings were animal forms with bold lines and colors. The color was limited to red, red-brown and black pigments. When man eventually turned to settled communities, the practice of wall painting continued and was used for decorating the interiors of houses and shrines.

For painters of ancient Egypt and the Near East the paintings were devoted mainly to the decoration of ceilings and the walls of royal tombs, temples, and palaces. Non-religious paintings centered on the events surrounding the life of the Pharaoh while others had themes of religious significance.

The painting medium used throughout the ancient world consisted of tempera, a mixture composed of color pigments extracted from minerals, egg yolk used as an adhesive, and water to liquefy the paint. The surface to be painted upon was often prepared with a thin coating of plaster. The easiest method of working was to apply the paints to the dry surface. As use of the medium progressed, tempera was applied to the plaster while the surface was still wet. This method was known as true fresco. Decorating wall surfaces with fresco paintings became more prominent throughout the Roman, Byzantine, Romanesque, and Renaissance periods. Perhaps one of the most important artists during the Renaissance was Michelangelo who painted a fresco on the ceiling of the Sistine Chapel.

Art History. Students research the use of tempera painting and frescoes by various artists during different periods of art history. Information to be discovered in researching would be how these artists prepared their paints and the type and sources of pigments used in their paintings.

Art and History. A variation on this activity could be for students to create their own "cave paintings." In this way, students would be using tempera (albeit a modern version) while at the same time depicting life of cave dwellers. This requires some research into how cave dwellers survived and what they ate. Students could discuss how the light in the cave might determine how much paint was used. Encourage students to discuss whether the light in the cave, the availability of light, or a combination of both would make a difference.

ARTIST VIGNETTE: ROMARE BEARDEN

Romare Bearden is considered to be America's premier collagist, and has often been referred to as on of the most notable African American artists of the twentieth century. Bearden's career began in the early 1940's. He later turned to collage in 1963 as his primary art medium. Born in Charlotte, North Carolina, much of Bearden's childhood was spent in Harlem, New York. While in New York, he was exposed to many artists and jazz musicians by his father. It was due to this early exposure that he constantly incorporated his love of music into his art. Bearden received his formal education at Columbia University in New York, where he earned his degree in mathematics. Although he later studied philosophy and art history in Paris, he never had formal training in making art. This did not stop him from following his heart and pursuing something that he truly loved to do.

Emerging at the height of the civil rights struggle in the 1960's as a major artist, he created "photomontage projections" which were made of images snipped from newspapers and magazines, then enlarged photographically. Considered by many to be a daring innovator, he used art-making processes that could be considered primitive. Among these were paste-up, photographic copying and enlargement. However primitive these techniques appeared, their impact was great.

Activity

Photomontage is a type of art that can be used by students to produce a group project with a theme. For example students can create a photomontage with the theme "The Impact of Color". Students can look through old magazines and newspapers and cut and paste pictures of colorful objects that may attract a person's attention and perhaps persuade them to buy an object. It may be clothing, furniture, or automobiles. Members of the group would then give a title to their artwork, such as "Color and Cars".

Students choose a current issue and represent it with a photomontage. Encourage students to share their projects and explain how it represents their vision of a particular issue. For example, students might choose to represent animal rights, endangered species, or something happening at school.

ACTIVITY 9

Investigating the World of Colors

What we notice most about light is color. We see colors the way we do because of the way light is reflected or absorbed. The reason something appears red is because all of the colors in white light are absorbed except red. The red light is reflected to our eyes and so we see the color red.

The human eye is sometimes compared to a camera. It collects information and sends it to the brain. The retina acts like the "film" of the eye. It is made of two types of cells, rods and cones. Rods are the cells that let us see light and motion, and cones are cells that allow us to see an object clearly and in color.

Color comes from the visible spectrum of light. In any system of colors, those that cannot be mixed from any of the others are called primary colors**.** The primary colors of light are red, green and blue. From these three colors every other color of light can be made.

Paint pigments mix differently than light. The type of color mixing familiar to artists is done with paints or pigments, not lights. Primary pigments in paint can vary, however red, yellow and blue are the most common ones.

In two investigations you will be exploring how our eyes see color, how artists mix the primary colors of pigment to produce secondary colors, and how we use color wheels to observe the relationship between primary colors, secondary colors and complementary colors.

Materials:

- ☐ White unlined paper
- ☐ Science Notebook
- ☐ Water
- ☐ Watercolor paints
- ☐ Paintbrush
- ☐ Container for holding water
- ☐ Blank color wheel
- ☐ 3 different colored markers or other objects that are the same size and shape

Investigation I

1. In this activity you will need a partner, 3 different colored objects such as markers or pencils, and your Science Notebook.

2. One partner sits down and faces forward while the other partner stands behind.

3. The person that is standing chooses one of the three colored objects and moves the object slowly around the right side of their partner's head.

[The partner that is sitting should be looking straight ahead and should not shift his or her eyes during this experiment.]

4. The seated partner should say "Stop!" at the very first moment he sees the object, and writes in his or her Science Notebook the color of the object.

5. In your Science Notebooks describe what happened. Where was the marker when the person sitting said "Stop?" Was the color of the marker identified?

6. Repeat until all three objects are tested and then change jobs.

7. Record in your Science Notebooks the following:

    - What was the first thing that you saw once your partner started moving the object?

    - Where were you able to see the best color?

    - Of the three colored objects that were tested, how many of them were you able to identify? Why do you think this is so? Can you explain what happened?

    - If you were to go home and tell your parents what you did in this activity, how would you explain to them how and when you see colors?

8. Use books, websites, or other resources to find out how we see color. Identify the structures in the eye that allow us to see color.

Investigation II

You are going to experiment with mixing colored pigments. You will need your blank color wheel and your Science Notebook to answer questions as you do this activity. You will also need the three primary colors of either tempera paint or watercolors. They are red, yellow, and blue.

1. Color the red, yellow and blue sections of the color wheel.

2. On a piece of paper mix the primary colors to get the secondary colors to fill in the blanks on the color chart. Answer the questions below in your Science Notebook.

    - Identify the color you added to the color chart.

    - What colors did you mix to get each of the secondary colors?

    - Explain how you decided which colors to mix and how much of each color you used.

The colors opposite each other on the color wheel, such as blue and orange, are called complementary colors. In you Science Notebook, write a statement about how you can use compementary colors. What happens when you mix complementary colors?

Collect magazines and cut out pictures that show complementary colors. Create a collage and then describe any new ideas you have about complementary colors in your Science Notebook. You can create a painting using primary colors or secondary colors. Many artists chose to either paint works of art emphasizing primary colors or secondary colors. Artists such as Henri Matisse, Pablo Picasso, Piet Mondrian, Katsushika Hokusai, and Frieda Kahlo emphasized primary colors in their work; Paul Cezanne, VictorVasarely, and Georgia O'Keefe emphasized secondary colors.

Activity 10

Using Learning Centers to Investigate Special Properties of Light

The Activity consists of four parts:

1. A general description with teacher background for each center,
2. A materials list for each center,
3. "What will the students do?" described for each center,
4. Student Pages.

Many unique properties of light can be investigated in the classroom by using learning centers. The length of time needed to complete these activities varies depending on the number of students in the classroom and the available time for study. Suggestions for how to design and use discovery centers can be found in the Introduction of this Guidebook.

This activity supports the inquiry-based classroom if you encourage students to ask and answer questions. Experiences at the centers can provide data for students to record, analyze and use to learn more about the world around them.

What do I need to think about ahead of time?

1. Through large group and small group discussion, encourage students to form questions that can be answered using materials at the centers.

2. Familiarize yourself with each center and gather materials as indicated for each center.

3. Decide how you want to set up your room and make a plan so students can move around the room easily.

4. Make a rotation plan. For example, if a student begins at Center 1, she moves to Center 2. If a student begins at Center 6, she moves to Center 1. Each Center should take approximately the same amount of time so that students are not ready to change Centers before those ahead of them are finished.

5. Students should take their Science Notebooks to each Center to record their questions, answers, information, or data.

WHICH PROPERTY OF LIGHT ARE STUDENTS INVESTIGATING AT EACH LEARNING CENTER?

LEARNING CENTER 1: DIFFRACTION ACTION

Diffraction Action uses diffraction gratings to look at various types of lights. A diffraction grating acts like a prism, spreading visible light into its component colors. The light that you see from a light source is the sum of all these colors. Each color corresponds to a different frequency of light. The diffraction grating sorts light by frequency, with violet light (the highest frequency of visible light) at one end of the spectrum and red light (the lowest frequency of visible light) at the other.

LEARNING CENTER 2: DID YOU SEE THE LIGHT?

Did You See the Light investigates transparent, translucent and opaque objects. Many students understand that different objects allow more or less light to pass through them. This activity will allow them to investigate many common items and determine whether they are transparent, translucent or opaque. A *transparent* material allows light to pass through it and a clear image to form. A piece of glass would be an example of a transparent material. A sheet of waxed paper is *translucent*. Some light does pass through translucent materials, but most of the light is scattered. As a result images cannot be seen clearly through them. A piece of cardboard is *opaque*. Light cannot pass through it and no image can be seen through this material.

LEARNING CENTER 3: CD RAINBOWS

CD Rainbow uses a compact disk (CD) as a diffraction grating to look at different types of lights. The lines or grooves on a compact disk are equally spaced over the flat surface of the disk. As a result when light strikes the disk it is separated into its component colors. Depending on the type of light, the colors seen may vary from one type of light source to another.

LEARNING CENTER 4: SPINNING COLORS

Spinning Color investigates the additive properties of color using spinning disks. When two or more colors are quickly spun together, our eyes may perceive a different color altogether. This is because the brain has the ability to retain or remember individual colors and adds them together, creating a new color.

LEARNING CENTER 5: BENDING LIGHT

Bending Light investigates the refraction of light. Many students have seen mirages on the highway in which a puddle of water appears on the road on a dry day. As they approached the "puddle" it disappeared, but soon another imaginary puddle may have been seen in the distance. This disappearing puddle is called a mirage and is an example of the refraction of light. Mirages are tricks of the atmosphere, optical illusions caused when a layer of air next to the ground becomes superheated from heat stored in the soil or in dark pavement. The boundary between this hot, and therefore less dense air, and the cooler denser air above it bends the light rays that strike it, acting like a giant mirror or lens held parallel to the ground. Whenever light rays travel from one medium to another like from air to water, or water to air, refraction or bending of light occurs.

LEARNING CENTER 6: THE RELATIONSHIP BETWEEN LIGHT AND HEAT

Many students may not understand that light is not matter because it does not take up space, has no mass, and is not made of atoms. Visible light is one form of electromagnetic radiation, which is a form of energy. Since energy cannot be created or destroyed under ordinary conditions, light energy is often converted into heat energy. This center will investigate the connection between light and heat energy. Students will also be investigating how and why light colors are cooler than dark colors.

MATERIALS:

LEARNING CENTER 1: DIFFRACTION ACTION

- ❑ Diffraction grating

- ❑ Candle
- ❑ Lamp with a 60 W bulb
- ❑ Flashlight
- ❑ 2 Strings of tiny Christmas lights (1- colored and 1-white)
- ❑ Other types of lighting available in the classroom (e.g., sunlight, fluorescent lights, computer screen)
- ❑ Science Notebooks

Learning Center 2: DID YOU SEE THE LIGHT?

- ❑ Different materials, such as wax paper, brown paper, plastic milk container, construction paper, cardboard, aluminum foil, plastic wrap, foam meat tray, paper towel, or paper plate to be used to investigate transparent, opaque, and translucent materials
- ❑ Lamp with a 60 W bulb as the light source or a small high intensity lamp
- ❑ Science Notebooks

Learning Center 3: CD RAINBOWS

- ❑ Used CD's
- ❑ Flashlight
- ❑ Lamp with a 60 W bulb
- ❑ Sunlight
- ❑ Candle
- ❑ Science Notebooks

Learning Center 4: SPINNING COLORS

- ❑ 2 sharpened pencils
- ❑ Red, blue, yellow, green permanent markers
- ❑ Drawing compass
- ❑ Two 3x5 cards
- ❑ Scissors
- ❑ Science Notebooks

Learning Center 5: BENDING LIGHT

- ❑ Styrofoam cup
- ❑ Penny
- ❑ A container of water
- ❑ Scissors
- ❑ Transparent tape
- ❑ Science Notebooks

Learning Center 6: THE RELATIONSHIP BETWEEN LIGHT AND HEAT

- ❑ 3 containers of water
- ❑ 3 thermometers
- ❑ A sunny day
- ❑ A sheet of black construction paper and a sheet of white construction paper
- ❑ Tape
- ❑ Science Notebooks

WHAT WILL THE STUDENTS DO?

Students use any or all of the centers to answer the questions they developed before beginning the investigation. Be sure that questions are focused and well-articulated so that students can collect information at the centers.

LEARNING CENTER 1: DIFFRACTION ACTION

Students will use diffraction gratings to view the colors or spectrum produced by visible light.

- Students hold the diffraction grating in front of different light sources.
- They will record on their student page or in their Science Notebook the colors that they see when they view different types of light using the color chart that you provide or that they copy.
- Students may notice the intensity of the colors and the width of the color band produced.

LEARNING CENTER 2: DID YOU SEE THE LIGHT?

Students will be testing various materials to determine whether they are transparent, translucent or opaque.

- Students hold the different materials in front of a light bulb.
- They will then record the name of the material under the appropriate column on their student page or in their Science Notebook.
- Students will think of practical applications for the materials that they have observed.

LEARNING CENTER 3: CD RAINBOWS

- Students will observe features of the surface of a CD in different types of light: candle light, sunlight, light from a 60 W lamp, and a flashlight
- They will then describe any similarities or differences observed in the color spectrum with that observed at the DIFFRACTION ACTION Center.

Learning Center 4: SPINNING COLORS

- Students will use a compass to draw two circles 8 centimeters (cm) in diameter on the blank side of each of the 3x5 cards and divide it into 8 equal wedges
- On the first circle, color every other section red and blue. On the second circle, color every other section yellow and green.
- Students will push a pencil point through the center of each disk so that the colored sides are facing the pencils' erasers. For better balance they can keep the disk down near the point end of the pencil.
- Students will hold the pencil upright and spin it on the floor like a top and observe and record the color that the disk appears to be.

Learning Center 5: BENDING LIGHT

- Students work in partners and place a penny at the bottom of a foam cup that has been cut in half.
- One partner will slowly slide the cup away from the other just until they can no longer see the penny.
- Without disturbing the penny, one partner will slowly pour water into the cup until the penny can be seen again.
- Remind the students that they should not be moving or changing position during this activity.
- They will record what happened and why in their Science Notebooks.

Learning Center 6: THE RELATIONSHIP BETWEEN LIGHT AND HEAT

- Students observe how dark surfaces absorb light, and light colored surfaces reflect light by making two different colored holders for their thermometers, one that is made of black construction paper and one that is made of white construction paper. Students will place the two covered thermometers outside in full sun for 2-3 minutes, and then read and record the temperatures in their Science Notebooks.
- Students will go outside and measure the temperature of three containers of water that they placed outside at least 1 hour prior to the activity. Place one container in full sun, one in part sun/part shade, and a third container in full shade.
- Students will place the thermometer in the container for at least 1 minute without moving the cups and measure the temperature of the water in each container.
- Students will then record the temperature in their Science Notebooks.

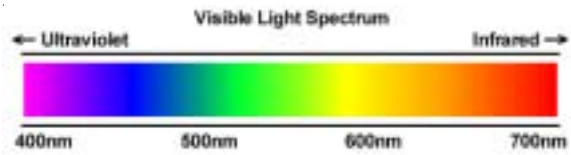
ACTIVITY 10

Using Learning Centers to Investigate Special Properties of Light

LEARNING CENTER 1: DIFFRACTION ACTION

At this center you will be using a diffraction grating to look at different types of light. A diffraction grating works kind of like a prism in that it will separate light we can see into the colors that make it up.

Each color has a certain wavelength with violet being the shortest wavelength, and red being the longest wavelength. The other colors that you might see in the spectrum are usually in this order: red, orange, yellow, green, blue, indigo and violet.



As you look at each type of light with the diffraction grating record what you seee in your Science Notebook. You can use a chart like the one below to record your data if you wish.

violet	indigo	blue	green	yellow	orange	red

Describe the diffraction grating.

What do you think is happening to the light?

ACTIVITY 10

Using Learning Centers to Investigate Special Properties of Light

LEARNING CENTER 2: DID YOU SEE THE LIGHT?

At this center you will place different objects up to a light and decide whether the object is transparent, translucent or opaque. If it is *transparent* then the light will pass through it and a clear image will form. If an object is *translucent*, it will allow some of the light to come through, but most of the light is scattered. In a translucent material you can see an object through the material, but it will not be clear. In an *opaque* material, all the light is blocked and you will not be able to see through this material.

As you hold the objects up to the light, record your answers in a chart like the one below. For example if you held a piece of glass up to the light, you could see through it and what you would see would be clear. You would write the word "YES" in the transparent column.

Object	Transparent	Translucent	Opaque	General Observations

Now, answer the following questions in your Science Notebook:

1. What type of material would you want a computer screen to be made of: translucent, transparent or opaque? Explain your choice.
2. Why would you want a flashlight bulb to be made of a transparent material?
3. Why would you want your sunglasses to be made of a translucent material?
4. What type of object, a transparent, translucent or opaque one, would you use to make a shadow?

ACTIVITY 10

Using Learning Centers to Investigate Special Properties of Light

LEARNING CENTER 3: CD RAINBOWS

At this center you will be using a compact disk (CD) to look at light from several different sources. Look at the surface of a CD. In your Science Notebook describe what the surface looks like.

Move the CD and try to allow some of the light from overhead to hit its surface. Record what you see in your Science Notebook, or create a chart like you did at Learning Center 1: Diffraction Action.

Use the CD to look at light from a flashlight, a lamp with a 60 W bulb, sunlight from a window, and a candle. Record the colors that you were able to see in your Science Notebook.

In your Science Notebook explain what happened and why you think it happened. Compare your answer with another student. Write your "theory" about what happened.

ACTIVITY 10

Using Learning Centers to Investigate Special Properties of Light

LEARNING CENTER 4: SPINNING COLORS

At this center you will create and observe a spinning color disk .

1. Use the compass to draw 2 circles 8 centimeter in diameter on the blank side of each of the two 3x5 index cards.

2. Divide each circle into 8 equal wedges. On the first circle use the red and blue markers. Color every other section red and blue.

3. On the second circle use yellow and green markers and color every other section yellow and green.

4. Cut out each of the circles. Push a pencil point through the center of the red and blue circle, and take another pencil and push the point through the center of the yellow and green circle with the colored side facing the pencil's eraser. For better balance, keep the disk down near the point end of the pencil. Put the point of the pencil on the floor and spin it like a top. Do this several times and record what happens in your Science Notebook.

5. In your Science Notebook, draw what you see. Then, describe in words what happens as the top slows down. Compare your drawing and results with another student. How can you explain what is happening?

ACTIVITY 10

Using Learning Centers to Investigate Special Properties of Light

LEARNING CENTER 5: BENDING LIGHT

At this center you will observe how light bends, or refracts, to form an image. Work with a partner.

1. Place a penny at the bottom of a styrofoam cup that you have cut in half.

2. Have your partner slowly slide the cup away from you until you can no longer see the penny. **Do not move. Stay in this position until your partner has completed Step 3 below.**

3. Without disturbing the penny, your partner will slowly pour water into the cup until you can see the penny again. Record what happened in your Science Notebook and switch jobs.

4. In your Science Notebook answer the following questions:

   What did you observe?

   Can you explain what is happening when you add the water?

5. In your Science Notebook, draw the path that light takes from the penny to your eye before and after the water was added. You may use arrows to show what happens to the light.

ACTIVITY 10

Using Learning Centers to Investigate Special Properties of Light

LEARNING CENTER 6: THE RELATIONSHIP BETWEEN LIGHT AND HEAT

Are light and heat related? In your Science Notebook, write any ideas or questions you have about the relationship of light and heat. Before you begin, go outside with 3 cups of water. Put one in full sun, one in part sun/part shade, and one in full shade.

1. Use a piece of black construction paper and tape to make a cover for a thermometer. Seal one end of the cover so that the thermometer does not fall out.

2. Do the same thing with a white piece of construction paper for a second thermometer. Take the two covered thermometers outside and place them in full sun.

3. Predict what you think will happen if you leave these two covered thermometers outside in full sun. Write your predictions in your Science Noterbook.

4. Wait 2-3 minutes and read the temperature on each of the two thermometers by gently sliding them out of the cover. Record the temperature.

   Thermometer covered with black paper _____degrees Celsius.

   Thermometer covered with white paper _____degrees Celsius.

How did your predictions compare to your measurements? Explain what you think happened.

5. Think about the 3 containers of water you placed outside. Predict the temperature of the water in each. Record your predictions in your Science Notebook.

6. Take three thermometers outside, and without moving the cups, measure the temperature of the water in each cup. Record the temperatures in your Science Notebook.

Full sun _____degrees Celsius

Part sun/ Part shade _____degrees Celsius

Shady _____degrees Celsius

Were your predictions correct?

Compare your predictions with your results. Write about this in your Science Notebook. What can you say about the relationship between light and heat?

Are you thirsty yet?
Some people make "sun tea" You can do this by placing a tea bag in cold water in a clear jar and covering it with plastic wrap. After the water sits for awhile in the sun, it will turn from a clear color to a dark brown. Remove the tea bag, add sugar to taste, a couple of ice cubes, and you have delicious iced tea.

Student SELF-CHECK

Module 4: Light & Colors

Now that you have completed Module 4, answer the questions below in your Science Notebook.

1. Draw what happens as light passes through a prism.

2. Many people remember the colors of the rainbow or visible light spectrum by the initials ROY G. BIV. What are the colors?

3. How are rainbows made?

4. What are the three primary paint pigments?

5. Orange is a secondary color. What two primary colors do you mix to get this color?

6. If you looked on a color wheel, where would you find the complementary color for blue?

7. Give an example of an opaque object.

8. A friend asks you to hand him two objects, one that is translucent and one that is transparent. What items would you hand him?

9. A compact disk and a diffraction grating do the same thing to light. What happens when you reflect light off a compact disk? What is it about compact disks that create this effect?

10. What color shirt would you want to wear if you were outside on a sunny day? Why?