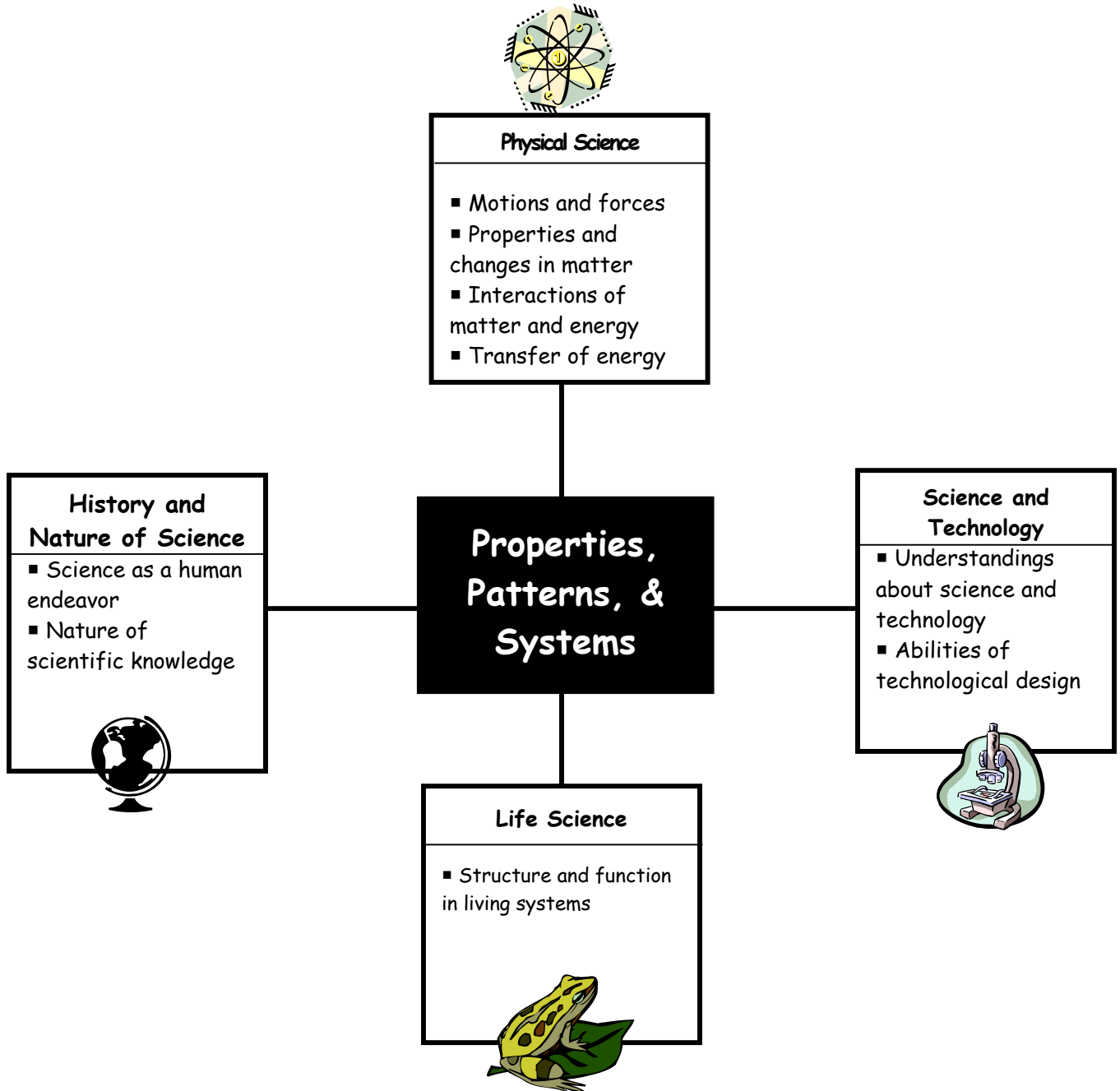


Intradisciplinary Connections

See pages 21-22 for the complete wording of the Texas Essential Knowledge & Skills addressed in this learning experience.



Overview of Learning Experiences

TEKS	<p>8.7 The student knows that there is a relationship between force and motion. The student is expected to:</p> <p>(B) recognize that waves are generated and can travel through different media</p>
Engage	<ul style="list-style-type: none"> ◆ Students observe and describe the spectra produced when using a diffraction grating to view the light produced by an incandescent light bulb.
Explore	<ul style="list-style-type: none"> ◆ Students rotate through lab stations to manipulate various materials to observe the refraction of light through different media.
Explain	<ul style="list-style-type: none"> ◆ Students communicate and analyze their results from the Explore activities. ◆ Students analyze a model to help understand the refraction of light. ◆ Students analyze a model to help understand the characteristics of a wave including crests, troughs, and wavelengths. ◆ Students compare their previous observations to actual data.
Elaborate	<ul style="list-style-type: none"> ◆ Students relate the refraction of light and wavelengths of color to the color of earth's sky.
Evaluate	<p style="text-align: center;">SUMMATIVE ASSESSMENT</p> <ul style="list-style-type: none"> ◆ The student plans and conducts an investigation to demonstrate an understanding of light as energy that travels through media as a wave.

ENGAGE

1. Distribute to each student a diffraction grating card. Explain that inside the square is a piece of material called a diffraction grating that has thousands of tiny parallel lines etched into it. Turn on the light bulb (75-100 watts) that is preferably placed in the center of the room near eye level of the seated students. Darken all other light sources in the room.

2. Have students hold the card up to their eyes while looking at the light bulb. By rotating the card, students will see a moving display of colors around the light bulb. Explain that each line of colors they are viewing is called a spectrum. Check to make sure that all students are seeing the display of colors. If not, invite student to move closer to the light, take off eyeglasses, move the card closer or further from eye, etc.

3. Instruct students to position the card so they have a spectrum running to the left and to the right sides of the light bulb. In their journal, have students use crayons or colored pencils to record their observations. Encourage students to make drawings as accurate as possible including the sequencing of colors and the relative width of each color band.

4. Have students share their observations by discussing the following types of questions:

Questioning Strategies

- What colors did you see to the left of the light? (*red, orange, yellow, green, blue, violet*)
- What colors did you see to the right of the light? (*violet, blue, green, yellow, orange, red*)
- What examples of patterns did you find in your observations? (*acknowledge all responses; colors on left match colors on right but in reverse*)
- Where do you think the colors came from? (*acknowledge all responses*)

Materials (details p. 12)

For the class:

- light bulb and socket

For each student:

- journal
- diffraction grating card
- crayons or colored pencils

ENGAGE

Grades 6-8

Students should know that light is made up of a mixture of many different colors of light, even though to the eye the light looks almost white.

Benchmarks for Science Literacy, p. 90

EXPLORE

1. Set up enough containers of materials for small groups of students to use as they rotate through 3 different stations. For example in a class of 30 students, set up 3 containers of materials at each station. This will allow groups of 3-4 students to work together and move through the three different activities.

2. Explain to students that their job is to make careful observations about the behavior of light at each of the three stations they will visit with their team. Emphasize the importance of recording detailed information in journals, as they will use this data later.

3. Allow ample time for students to manipulate materials, discuss observations, and make detailed records in their journals. Encourage students to make drawings as accurate as possible and use labels as needed.

4. Circulate through the working student groups while making formative assessments and redirecting student thinking as needed.

* Note: Students should be encouraged to observe many things at each station, but listed below are the primary observations that students should not neglect:

→ Lab Station One:

A pattern of colors will form although students may not observe all of ROYGBV.

→ Lab Station Two:

The pencils will appear broken when viewed from the side.

→ Lab Station Three:

An inverted image of the window and the scene outside will be projected onto the white paper.

Materials (details p. 12)

For each group:

Station One

- prism
- flashlight
- access to darkened area
- crayons or colored pencils
- Lab Station One* card, Master A

Station Two

- pencil or straw
- glass jar
- water
- oil
- Lab Station Two* card, Master B

Station Three

- hand lens
- access to sunny window or door
- white paper
- Lab Station Three* card, Master C

For each student:

- journal

EXPLAIN

1. Have students communicate their findings for Lab Station One by sharing their drawings, descriptions, and list of questions. Be ready to ask the following types of questions if students do not bring up the information on their own during the class discussion:

Questioning Strategies

- What colors did you observe? Was there a pattern? (*acknowledge all responses*)
- Why did this setup work to make a pattern of colors on your paper? (*acknowledge all responses*)
- What questions did your group generate? (*compile class list*)

2. Have students communicate their findings for Lab Station Two by sharing their drawings, descriptions, and list of questions. Be ready to ask the following types of questions if students do not bring up the information on their own during the class discussion:

Questioning Strategies

- What are two things about the pencils that appeared to change? (*shape because they looked broken and size because sometimes they looked bigger*)
- Why did this setup work to make the pencils look different? (*acknowledge all responses*)
- What questions did your group generate? (*compile class list*)

3. Have students communicate their findings for Lab Station Three by sharing their drawings, descriptions, and list of questions. Be ready to ask the following types of questions if students do not bring up the information on their own during the class discussion:

Materials (details p. 13)

For the class:

- signs: crest, trough, wavelength, Masters E-G
- diagram of wave
- brightly colored rope
- poster or transparency of wave definition, Master D

For each group of students:

- toy car (no axle)
- cardboard square
- Modeling Light* lab card, Masters H-J

For each student:

- journal
- The Colors of Visible Light*, Master K

- What are two ways that the picture you observed on your white paper is different from what you actually observed outside the window? (*picture is smaller and inverted or upside down*)
- What other piece of science equipment have you used that makes things appear inverted? (*microscope*)
- Introduce "image" as a term to describe a visual representation or picture.
- Why did this setup work to make an image on your paper? (*acknowledge all responses*)
- What questions did your group generate? (*compile class list*)

4. After students have shared information collected at all three lab stations, discuss the following:

- At all three of our stations, what was the one thing we were investigating? (*behavior of light*)
- In all three activities, light was being bent as it traveled through a material. At Lab Station One, what was bending the light? (*prism*)
- At Lab Station Two, what was bending the light? (*jar of water and oil*)
- At Lab Station Three, what was bending the light? (*hand lens*)
- Why do you think light bends when it travels through these materials? (*acknowledge all responses*)

5. Explain to students that they are going to study a model to help explain why light bends when it travels through different materials. It will be important for students to make very careful observations and

remember that models are used to help study things that we cannot observe directly. However, models do have limitations and are never exactly like the real thing.

6. Distribute materials to each group. Have students complete the activity as they actively share observations.

7. Conduct the following discussion with students:

- What did you observe about the behavior of the toy car? (*traveled in straight line until hitting the plastic material, then slowed down and changed path*)
- Actually two things changed about the car's motion. Can you name them? (*speed and direction*)
- Why did these two things change? (*front wheel that hit the material first slowed down first because of increased friction; other wheel had to catch up causing change in direction*)
- How can this model help us understand the behavior of light as it travels through different materials? (*light rays hit new material, slow down, and change direction much like the car did; we can observe the car's motion but not the light's motion*)
- How is this model different from the behavior of light traveling through different materials? (*car moves much, much slower than light and car is much, much larger than light ray; light actually travels through the material whereas the car traveled on top of the material*)
- How does this model explain why the colors of light were displayed by the prism and diffraction grating? (*acknowledge all answers*)

Grades 6-8

Student should know that models are often used to think about processes that happen too slowly, too quickly, or on too small a scale to observe directly.

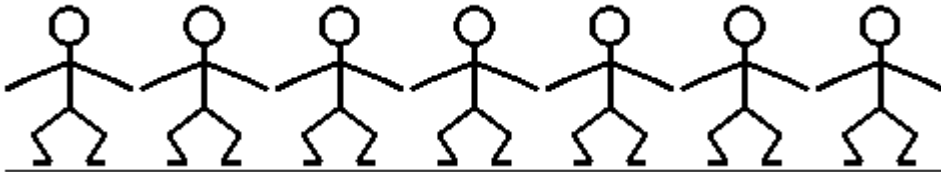
Benchmarks for Science Literacy, p. 269

Grades 6-8

Students should know that an unbalanced force acting on an object changes its speed or direction of motion, or both.

Benchmarks for Science Literacy, p. 90

8. To understand the different colors that make up light, explain to students that they are going to study a second model. Have students stand up and form a line around the perimeter of the room facing the center. Students should be closely spaced. Ask students if they have ever participated in a "wave" at a sporting event or concert. Explain that you want them to send a "wave" around the room. Have all students place their hands palms down on the front of their legs. Designate one student to begin the wave by moving hands and arms slowly upward above the head and back down to the original position. Have each student follow suit. It may require two or three tries for everyone to understand the movement.



9. Display the definition for "wave" as stated in the box above. Have students read the definition and discuss how their model compares to the definition. The wave in the model is the disturbance that travels down the line of students. However, none of the individual students are actually carried with the wave as it travels—they all remain standing in their same location. The main point is that all waves are traveling energy; light waves consist of energy in the form of electric and magnetic fields vibrating at right angles to each other and therefore are referred to as electromagnetic radiation.

10. Once students are comfortable in their discussion of defining a wave, start the wave model again explaining that this time when you say "freeze" everyone "freezes" in place. Once "frozen", have students observe the position of students' hands. Using a sign labeled "crest",

wave, wāv, *noun*
A disturbance that transfers energy progressively from point to point in a medium

Webster's Dictionary

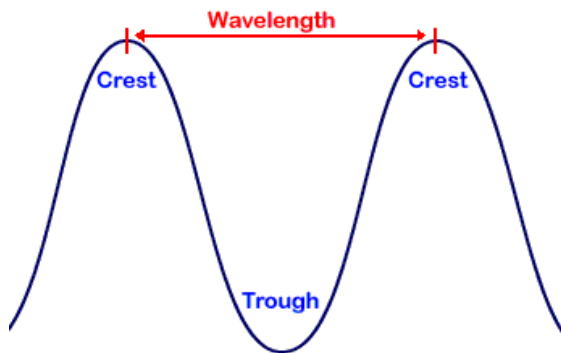
EXPLAIN

Grades 6-8

Students can now learn some of the properties of waves by using water tables, ropes, and springs, and quite separately they can learn about the electromagnetic spectrum, including the assertion that it consists of wavelike radiations. Wavelength should be the property receiving the most attention but only minimal calculation.

Benchmarks for Science Literacy, p. 90

designate that the highest point on the wave is called a crest. Using a sign labeled "trough", designate that the lowest point on the wave is called a trough. Using a sign labeled "wavelength", have one "crest" hold one end of the yarn while the next consecutive "crest" holds the other end of the yarn. Designate that the distance between two consecutive points on a wave is called a wavelength. Explain to students that they have just made a human model of an important concept in physics called a wave and that light is energy that travels as a wave. Have students do the wave again this time holding onto a brightly colored rope. This allows the shape of the wave to show up clearly.



11. Use a diagram to show students a wave labeling the parts of crest, trough, and wavelength. Explain again that light is energy that travels in waves. However, not all parts of light are of the same wavelength. The human eye actually sees different wavelengths as different colors.

12. Have students complete *The Colors of Visible Light* data sheet.

13. Discuss with students the following:

- How did your observations from the diffraction grating activity compare to the actual data about wavelengths of visible light? (*acknowledge all responses*)
- How did your observations from the prism activity compare to the actual data about wavelengths of visible light? (*acknowledge all responses*)
- Does anyone know a word that can be used to describe the bending of light as it passes through different materials? (*refraction*)*
- In Science, we also use the word "medium" to describe the material through which waves pass. "Media" is the plural form of "medium." What are some media that we observed light travel through? (*air, water, oil, plastic prism, plastic hand lens, glass window, etc.*)
- In each of these examples, what are two ways that the light rays changed as they traveled across boundaries between the media? (*speed and direction*)
- Which wavelengths of light were bent the most? (*blue and violet end of spectrum*)
- Which wavelengths of light were bent the least? (*red end of spectrum*)

* Note: Refraction and diffraction both involve processes that cause light to bend. For most students this is an adequate explanation. However, the processes of refraction and diffraction are not exactly the same and for advanced students further research may be desired.

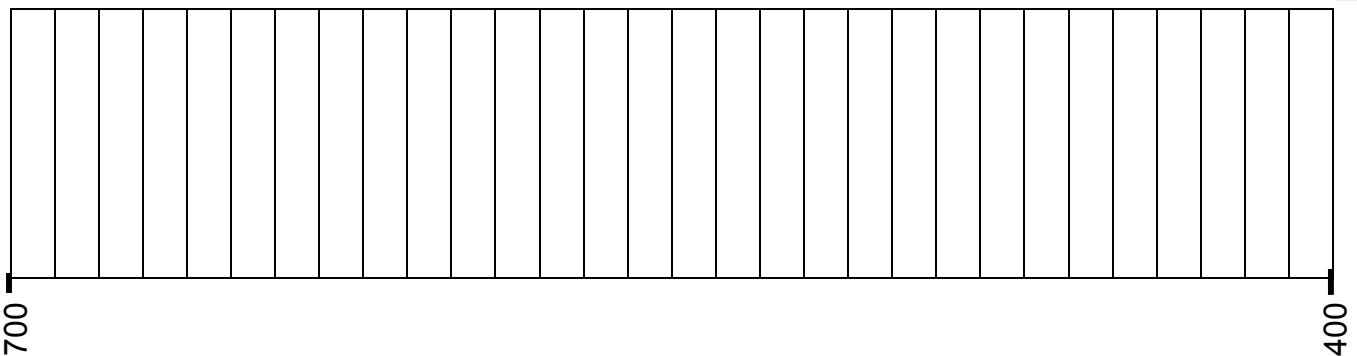
The Colors of Visible Light (See Master K)

The **wavelengths** of visible light are measured in units called **nanometers**. One nanometer unit equals one billionth of one meter. The boundaries, in nanometers, for the wavelengths of each color are listed below:

COLOR	BOUNDARIES
red	700 to 630 nm
orange	630 to 580 nm
yellow	580 to 530 nm
green	530 to 490 nm
blue	490 to 430 nm
violet	430 to 400 nm

On the grid below, mark off bands for the colors of visible light. Use the line across the bottom of the grid to record nanometer units numbered from 700 on the left to 400 on the right. Mark off the proportionate widths for each band and color appropriately. Blending colors at the boundaries can make the spectrum more realistic-looking.

THE SPECTRUM OF VISIBLE LIGHT



Cut out the box on the dotted line and glue into your journal. Beneath the box, write about the following:

Refer back to your earlier journal drawings when you used the prism and diffraction grating. How do your results from these previous activities compare to the spectrum you colored based on the actual data of wavelengths. For example, are the colors in the same sequence? Are the widths of the color bands similar? Write a paragraph describing your comparison of data.

ELABORATE

1. Ask students to think, pair, and share an answer to the following question: Why is the sky blue?
2. Allow each table group to share their thoughts about the reason for our planet's blue sky. (*acknowledge all responses*) Use two volunteers to conduct the following demonstration in a darkened room.
 - "Student A" is going to shine this light through the container of water and onto a piece of white cardboard placed on the other side. What do you predict will happen? (*acknowledge all responses*)
 - Have "Student A" shine the light through the container of water. In journals, have students draw the setup and record the color of the light on the cardboard. (*white*)
 - Have "Student B" add 2 tablespoons of powdered creamer to the container of water and stir. Have "Student A" shine the light through the mixture and onto the white cardboard. Have students draw the setup and record the color of the light in the mixture from the side view (*blue*) and on the cardboard. (*reddish*) If color change did not occur, add more creamer and stir.
 - In groups, have students discuss how this model explains why we see a blue sky and a reddish sunset. (*particles in creamer scattered light like dust and other particles in atmosphere scatter light; blue wavelengths are shorter and scatter easier than longer red wavelengths; blue light goes out in all directions and is reflected back to earth making sky appear blue; longer red wavelengths are not easily scattered and thus pass through and onto the cardboard*)

Materials (details p. 13)**For the class:**

- water
- transparent container
- stirring rod or spoon
- flashlight
- powdered creamer
- white cardboard

3. Have students work in pairs to use the Internet and/or other resources to research about how and why the human eye perceives colors. For example, "Why does grass look green?" or "Why does a rose look red?" A list of recommended websites is listed below. If students do not have access to the Internet, other resources from the school library could be utilized. Students should be prepared to present their findings to the class using a visual.

Grades 6-8

Students should know that human eyes respond to only a narrow range of wavelengths of electromagnetic radiation—visible light. Differences in wavelength within that range are perceived as differences in color.

*Benchmarks for
Science Literacy, p. 90*

ELABORATE

Recommended Websites:

Colorworm teaches about color and light

<http://php.iupui.edu/~pellison/colorworm/home.html>

Digital Learning Center: Chapter II, What is Color?

http://www.kodak.com/US/en/digital/dlc/book3/chapter2/digColorM1_1.shtml

Star Light, Star Bright

<http://amazing-space.stsci.edu/light/star-light-science.html>

Vision Science

<http://www.visionscience.com>

How We See: The First Steps of Human Vision

http://www.accessexcellence.org/AE/AEC/CC/vision_background.html

EVALUATE

1. In groups, have students review the compiled list of questions the class generated and identify the ones they believe are both testable and interesting. Using one of those questions from the list or another one that the group develops, have students plan and implement an investigation. Provide a scoring rubric so that students will have a clear understanding of the expectations for their task. Set out a display of possible materials that students may use during their investigation.
2. Have each student group write and turn in a plan for teacher approval including the question they want to answer, the materials they will use, and the procedures they will follow. After receiving teacher approval, allow students adequate time to complete the investigation and prepare their presentation.
3. Have each group discuss and complete a self-evaluation based on the rubric.
4. Have each group present their investigation to the class.

Materials (details p. 14)

For the class:

- acrylic prisms
- water prisms
- flashlights
- food coloring
- thermometers
- cellophane in different colors
- diffraction grating cards
- assortment of transparent containers
- radiometers

For each student:

- Inspecting the Spectrum Scoring Rubric, Masters L-M*

Grades 6-8

Care should be taken, in an effort to cover content, not to stop fostering curiosity. Time need to be found to enable students to pursue scientific questions that truly interest them. Inquiry projects, individual and group, provide that opportunity.

*Benchmarks for
Science Literacy, p. 286*

Inspecting the Spectrum (See Masters L-M) Scoring Rubric

A. Experimental Design	The problem is clear and testable. A valid, practical procedure is presented in a logical sequence to allow gathering of accurate data suitable for analysis to accomplish the task.	4
	The problem is clear and testable. Valid, practical procedure is presented that contains errors or omissions that may hinder the gathering of accurate data suitable for analysis to accomplish the task.	3
	The problem is testable. A practical procedure with many steps insufficiently described or missing prevents the gathering of accurate data for the task.	2
	The problem is partially testable. The procedure is highly incomplete, and the method used to gather data is inappropriate for the task.	1
	The problem is not testable. The procedure is missing, or cannot generate useful data.	0
B. Data collection	The collected data and observations are complete, clearly and logically recorded, and consistent with the procedure. Measurements are precise. Technology used to develop a clear and attractive display of data in charts and graphs.	4
	The collected data and observations are fairly complete, clearly recorded, and fairly consistent with the procedure. Data is clearly displayed in chart or graph form.	3
	The collected data and observations have several omissions, recorded in a way that is difficult to interpret, and relate somewhat to the procedure. Data display is unclear.	2
	The data gathered is very incomplete, and is not related to the procedure. No charts or graphs of the data are included.	1
	No data or observations are recorded	0

C. Evaluation of Data and Conclusion	Clear communication of complete and accurate analysis of data and observations. Accurate conclusion is reached, which is supported by the analysis.	4
	Communication of complete but slightly flawed analysis of data and observations, which leads to a slightly inaccurate conclusion.	3
	Unclear communication of accurate conclusion with no analysis, or the analysis does not support the conclusion.	2
	Unclear communication of inaccurate conclusion with no analysis.	1
	No conclusion or analysis is present.	0
D. Lab Skills, Safety, and Participation	Selects and uses appropriate equipment with care and proficiency. Listens attentively, and stays actively involved in an organized approach.	4
	Uncertain about equipment selection, but uses equipment carefully. Listens to instructions and stays involved, but may wait for others to lead.	3
	Is not familiar with use of equipment, so chooses inappropriate equipment, but does not abuse equipment. Distracted during instructions, so must rely on others for directions.	2
	Uses equipment improperly, and is haphazard and disorganized. Is distracted during instructions, and needs constant reminders to stay on task	1
	Does not use equipment or abuses equipment. Is disruptive during instructions and activity.	0
	Total points	

Materials Detail Sheet

ENGAGE

For the class:

- light bulb and socket

Use a 75 - 100 watt bulb in any type of lamp without the shade.

For each student:

- journal
- diffraction grating card

Option 1: Purchase one sheet of diffraction grating from a science teaching supply vendor. Cut sheet into 2 cm x 2 cm squares. Cut 1.5 cm x 1.5 cm notches into the end of index cards. Tape a square of diffracting grating over notch in card. Do not allow tape to overlap viewing area.

Option 2: Use Rainbow Peepholes by Wren Enterprises 1-800-223-9080 (30 for \$8.95)

- crayons or colored pencils

EXPLORE

For each group:

Station One

- prism
- flashlight
- access to darkened area
- crayons or colored pencils
- Lab Station One* card, Master A

Station Two

- pencil or straw
- glass jar
- water
- oil
- Lab Station Two* card, Master B

Station Three

- hand lens
- access to sunny window or door
- Lab Station Three* card, Master C

Materials Detail Sheet

For each student:

- journal

EXPLAIN

For the class:

- poster or transparency of wave definition, Master D
- signs: crest, trough, wavelength, Masters E-G
For wavelength sign, punch one hole in each end. Secure yarn in each hole leaving the ends of the yarn free.



- diagram of wave
- brightly colored rope (approximately 50')
Available from local discount stores (\$4)

For each group of students:

- toy car (no axle)
- cardboard square approximately 40 cm x 24 cm
- plastic mailing wrap approximately 24 cm x 12 cm
- Modeling Light* lab card, Master H-J
- scissors
- tape

For each student:

- journal
- The Colors of Visible Light*, Master K

Materials Detail Sheet

ELABORATE

For the class:

- water
 - transparent container
 - stirring rod or spoon
 - flashlight
 - powdered creamer
 - white cardboard
-

EVALUATE

For the class:

- acrylic prisms
- water prisms
- flashlights
- food coloring
- thermometers
- cellophane in different colors
- diffraction grating cards
- assortment of transparent containers
- radiometers

For each student:

- Inspecting the Spectrum Scoring Rubric, Master L-M*

Background Information for Teachers

Light is a form of radiant energy that travels in waves. Since Greek times, scientists have debated the nature of light. Physicists now recognize that light sometimes behaves like waves and at other times like particles. When moving from place to place, light acts like a system of waves. In empty space, light has a constant speed of nearly 299,792 kilometers per second.

Light is a form of electromagnetic radiation. An electromagnetic wave consists of an electric field and a magnetic field positioned at right angles to each other and to the direction of motion of the wave. The source of all electromagnetic waves is a charge that is changing speed or direction. Electrons (which are subatomic particles with negative charges) jumping between different positions within an atom, for example, produce visible light.

Light waves can travel in a vacuum but that does not mean that they cannot travel through a medium. For example, light can travel through a medium such as the atmosphere or it can travel without a medium such as through space. A wave of light travels in a straight line until it encounters a boundary into some other material. If the light hits a transparent material at an angle, the light will bend or refract slightly altering the speed and direction of the light ray. Light of different colors bends different amounts. Blue light has a shorter wavelength than red light and thus is refracted a greater amount than red. Green light has an intermediate wavelength and is refracted an amount in between that of blue and red. The shorter the wavelength, the more bending there will be. Because each wavelength of light is refracted a different amount by objects such as prisms and water drops, white light is spread into an array of colors forming the pattern of red, orange, yellow, green, blue, and violet.

Our eyes interpret light of different wavelengths as different colors. If an object reflects red, then we see red. If an object reflects green, then we see green. Objects that reflect all wavelengths of light appear white while those that absorb and hold in almost all wavelengths of light appear black. When light enters our eye, it is refracted and then focused on the retina located on the rear surface of the eye. The image that falls on the retina is transferred and interpreted by the nervous system. Some of the nerve cells in the retina are called cones and are responsible for our seeing colors. Each cone is sensitive to a particular wavelength of light.

Targeted



Texas Essential Knowledge & Skills



Science TEKS

8.1 The student conducts field and laboratory investigations using safe, environmentally appropriate, and ethical practices. The student is expected to:

(A) demonstrate safe practices during field and laboratory investigations

8.2 The student uses scientific inquiry methods during field and laboratory investigations. The student is expected to:

(A) plan and implement investigative procedures including asking questions, formulating testable hypotheses, and selecting and using equipment and technology;

(B) collect data by observing and measuring;

(C) organize, analyze, evaluate, make inferences, and predict trends from direct and indirect evidence;

(D) communicate valid conclusions; and

(E) construct graphs, tables, maps, and charts using tools including computers to organize, examine, and evaluate data.

8.3 The student uses critical thinking and scientific problem solving to make informed decisions. The student is expected to:

(A) analyze, review, and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information

(C) represent the natural world using models and identify their limitations

8.4 The student knows how to use a variety of tools and methods to conduct science inquiry. The student is expected to:

(A) collect, record, and analyze information using tools including beakers, petri dishes, meter sticks, graduated cylinders, weather instruments, hot plates, dissecting equipment, test tubes, safety goggles, spring scales, balances,

microscopes, telescopes, thermometers, calculators, field equipment, computers, computer probes, water test kits, and timing devices

8.7 The student knows that there is a relationship between force and motion. The student is expected to:

- (A) demonstrate how unbalanced forces cause changes in the speed or direction of an object's motion; and
- (B) recognize that waves are generated and can travel through different media.

References

Benchmarks for Science Literacy. Oxford University Press, New York, 1993.

Broekel, Ray. *Experiments with Light*. Children's Press, Chicago, 1986.

Hewitt, Paul G. *Conceptual Physics*. Little, Brown, and Company, Boston, 1987.

Levine, Shar, and Johnstone, Leslie. *The Optics Book*. Sterling Publishing Co. Inc, New York, 1998.

Main, June, and Eggen, Paul. *Developing Critical Thinking Through Science*. Critical Thinking Books and Software, Pacific Grove, California, 1991.

Nassau, Kurt. *Experimenting with Color*. Franklin Watts, New York, 1997.

National Science Education Standards. National Academy Press, Washington, D.C., 2001.

Sneider, Cary I., Gould, Alan, Hawthorne, Cheryll. *Color Analyzers*. Lawrence Hall of Science, University of California at Berkley, 1989.

Walpole, Brenda. *Science Experiments to Amuse and Amaze Your Friends*. Random House, New York, 1988.

Whyman, Kathryn. *Rainbows to Lasers*. Gloucester Press, New York, 1989.

Zubrowski, Bernie. *Making Waves: Finding Out about Rhythmic Waves*. Beech Tree Paperback Books, New York, 1994.

Websites

<http://www.phy.ntnu.edu.tw/java/propagation/propagation.html>