LIGHT AND OPTICS

Grade Level or Special Area: Third Grade
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Length of Unit: Five lessons (each lesson approximately 45 minutes); if extension activities are included, each lesson should be extended 30-45 minutes

I. ABSTRACT

In this unit, students apply the scientific method to understand light and optics. Through a series of experiments and questioning, students learn how light travels and how to control it by bending, reflecting and refracting light. They also learn how lenses improve peoples' lives and knowledge by bending and reflecting light.

II. OVERVIEW

A. Concept Objectives
   1. Students understand the processes of scientific investigation and design, conduct, communicate about, and evaluate such investigations. (Colorado Science Standard 1)
   2. Students understand that energy appears in different forms, and can move (be transferred) and change (be transformed). (Colorado Science Standard 2.2)

B. Content from the *Core Knowledge Sequence*
   1. Third Grade Science: Light and Optics (page 82)
      a. The speed of light: light travels at an amazingly high speed.
      b. Light travels in straight lines (as can be demonstrated by forming shadows).
      c. Transparent and opaque objects
      d. Reflection
         i. Mirrors: plane concave, convex
         ii. Use of mirrors in telescopes and some microscopes.
      e. The spectrum: use a prism to demonstrate that white light is made up of a spectrum of colors.
      f. Lenses can be used for magnifying and bending light (as in magnifying glass, microscopes, camera, telescope, binoculars).

C. Skill Objectives
   1. Students will demonstrate with a flashlight that light travels in a straight line.
   2. Students will form shadows by blocking the straight line with an opaque object.
   3. Students will write a paragraph, poem, or short story explaining what happens when light is blocked by an opaque object.
   4. Students will perform an experiment showing how light reflects off a mirror to create images.
   5. Students will conduct an experiment to observe how light is refracted when it passes through transparent materials such as water and lenses.
   6. Students will conduct an experiment to observe how light can be used to magnify images on a paper.
   7. The students will conduct an experiment to show that white light is made up of a spectrum of colors.
   8. The students will learn the spectrum of colors by using the acronym ROY G BIV.
   9. Students will identify different optical instruments that use lenses and mirrors to control light.

III. BACKGROUND KNOWLEDGE

A. For Teachers
   1. *The Optics Book: Fun Experiments with Light, Vision and Color* by Shar Levine and Leslie Johnstone
   2. *Optics for Kids* website, available URL: http://www.opticalres.com/kidoptx.html

B. For Students
   1. If students have studied The Human Body in third grade, their prior knowledge of the workings of the eye will be helpful to their understanding of light and optics.

IV. RESOURCES

A. Prism (Lesson Four)
B. Two pieces of cardboard (Lesson Four)
C. *The Magic Rainbow Makes a Rainbow* (Lesson Four)
D. Optical instruments – optional (Lesson Five)
E. Ray Box – this is an optional box that controls the light source for more accurate readings; students make this box on the first day; it can be used for all lessons (see Appendix K for directions)

V. LESSONS

Lesson One: Light Basics and Shadows (approximately 45 minutes)

A. *Daily Objectives*
   1. Concept Objective(s)
      a. Students understand the processes of scientific investigation and design, conduct, communicate about, and evaluate such investigations.
      b. Students understand that energy appears in different forms, and can move (be transferred) and change (be transformed).
   2. Lesson Content
      a. The speed of light: light travels at an amazingly high speed.
      b. Light travels in straight line (as can be demonstrated by forming shadows).
      c. Transparent and opaque objects
   3. Skill Objective(s)
      a. Students will demonstrate with a flashlight that light travels in a straight line.
      b. Students will form shadows by blocking the straight line with an opaque object.
      c. Students will write a paragraph, poem, or short story explaining what happens when light is blocked by an opaque object.

B. *Materials*
   1. Appendix A: one for the teacher, optional—one for each student
   2. Appendix B: one for each student
   3. Appendix C: one for each student
   4. Appendix D: one for the teacher
   5. Butcher paper: one for each student
   6. Flashlights, light bulbs, and/or a transparency projector
   7. Pencils
   8. White Paper
   9. Appendix K: optional – one for teacher
   10. See Appendix K for additional materials for optional activities

C. *Key Vocabulary*

1. *Opaque* material is material through which light cannot pass.
2. *Optics* is the study of light. (See Lesson Three for another definition.)

D. *Procedures/Activities*

1. Tell the students that you are going to start this next science unit with hints about the topic they will by studying. Give them the following hints and see if anyone can guess the topic.
   a. It is something we could not live without.
   b. We use it every day.
   c. Scientists use it in many different instruments.
   d. Our understanding of it has helped to create objects such as eyeglasses to help us see.
   e. Without it, the world would be very dark.
   f. It is found in nature, but is also made by man.
   g. It can be blocked, reflected, and bent.
   h. Your parents probably tell you to turn it off when you leave a room.
2. Tell the students that they will be learning about light in this unit as well as studying how light behaves.
3. In this lesson they will be learning about the speed of light, how light travels, and one way of controlling light.
4. Tell the students that the first thing they need to know is how fast light travels. Allow some students to guess at the speed. Tell the students that the speed of light is 186,000 miles per second (approximately 300,000 km). Light from the sun takes eight minutes to go 93 million miles to Earth.
5. To put this into perspective, tell the students to pretend that they are going on a family vacation to the Sun and they are going to drive there (they will have to pretend this since obviously no one can drive to the Sun). If they drove 60 miles per hour (approximately the speed mom and dad would drive on the interstate depending on where you live), it would take them 177 years to get there. In one second, though, light can go around the Earth four times.
6. The speed of light is amazingly fast. That is why we see lightning before we hear the thunder.
7. Tell the students that they will be studying many aspects of light using the scientific method. Review this method with the students using Appendix A.
8. Tell the students that their first question is, “How does light travel?” Have the students come up with a class hypothesis. Then, have a student shine a flashlight. Discuss the results and conclusion. They should conclude that light travels in a straight line. Tell the students that throughout this unit they will be experimenting to answer many questions about light.
9. Tell the students that one way light can be controlled is by blocking it with an opaque object. Discuss the vocabulary meaning of the word opaque. Have the students complete the vocabulary assignment on Appendix B either now or at the end of the lesson.
10. Ask the question, “What happens when light is blocked by an opaque object?” Have the students write this question down on their student page of the scientific method (Appendix C).
11. Then, tell the students to come up with a hypothesis based on what they already know about light.
12. Then, have the students perform the experiment in Appendix D. The students should record their results on Appendix C.

13. As a class, discuss the results and enter a class conclusion. The students should conclude that when light is blocked, shadows are formed. Shadows are a result of blocking light. Blocking light is one way of controlling light.
14. Optional: Read the poem S*hadow* to the students from the Fantastic Poems website: www.fantasticpoems.com/Poems/Shadow.html.
15. Optional: Create a ray box from the extension activities in Appendix K and perform some more fun experiments.
16. Tell the students that in the next lesson they will learn about a second way to control light.

E. *Assessment/Evaluation*
1. Students will be assessed on their understanding of shadows based on the conclusions they draw from the shadow experiment.
2. Students understanding of shadows will be assessed based on their explanation of the behavior of light in their writing assignments.

Lesson Two: Reflection (approximately 45 minutes)

A. *Daily Objectives*
1. Concept Objective(s)
   a. Students understand the processes of scientific investigation and design, conduct, communicate about, and evaluate such investigations.
   b. Students know that energy appears in different forms, and can move (be transferred) and change (be transformed).
2. Lesson Content
   a. Reflection
      i. Mirrors: plane, concave, convex
3. Skill Objective(s)
   a. Students will perform an experiment showing how light reflects off a mirror to create images.

B. *Materials*
1. Appendix B: each student should have this from Lesson One
2. Appendix C: one for each student
3. Appendix E: one for the teacher
4. Plane (flat) mirror: one for each group of students
5. Flashlight: one for each group of students
6. White paper or poster: one for each group of students
7. Spoon: one for each group of students
8. See appendix K for materials for optional experiments

C. *Key Vocabulary*
1. A r*eflection* is an image that is formed when light bounces off a mirror and reflects the image in its path.
2. A *plane* mirror is a flat mirror.
3. A *mirror* is a smooth surface that reflects light.
4. A *concave* object is curved inward like a bowl.
5. A *convex* object is curved outward like a sphere or outside of a ball.

D. *Procedures/Activities*
1. Review the last lesson with the students. Ask the students, "How does light travel?" "How fast does light travel?" "What happens when you block rays of light?" Have the students give the answers orally from the last lesson.
2. Tell the students that they are going to learn another way of controlling light. The first was by blocking it to form shadows.
3. Tell the students that this method of controlling light has to do with mirrors.

4. Tell the students that their question for this experiment is "What happens to light when you place a mirror in its path?"
5. Have the students write this question on their experiment records in Appendix C.
6. Allow the students a couple of minutes to develop their hypothesis.
7. Differentiation: Students who are struggling may partner up with other students to develop a group hypothesis.
8. Give the students the experiment in Appendix E. Allow them to perform the experiment with the mirrors. The students will have results for three different mirrors, concave, convex, and plane mirrors.
9. Discuss with the students why images are different for each of these mirrors.
10. Explain to the students that when a mirror is placed in the path of light, the light bounces off the mirror and reflects the image in the path of the mirror. This is called reflection.
11. Tell the students that they will learn more about the concave and convex shapes in the next lesson.
12. Have the students complete the vocabulary page for the above words.

E. *Assessment/Evaluation*
1. Students will be evaluated on their oral answers to the review questions from the last lesson.
2. Students will be assessed on their knowledge of how light is reflected by their results and conclusions from the reflection experiment.

Lesson Three: Lenses and Refraction (approximately 45 minutes)

A. *Daily Objectives*
1. Concept Objective(s)
   a. Students understand the processes of scientific investigation and design, conduct, communicate about, and evaluate such investigations.
   b. Students know that energy appears in different forms, and can move (be transferred) and change (be transformed).
2. Lesson Content
   a. Lenses can be used for magnifying and bending light (as in magnifying glass, microscopes, camera, telescope, binoculars).
3. Skill Objective(s)
   a. Students will conduct an experiment to observe how light is refracted when it passes through transparent materials such as water and lenses.
   b. Students will conduct an experiment to observe how light can be used to magnify images on a paper.

B. *Materials*
1. Appendix B: students should already have this from previous lessons
2. Appendix C: two per student
3. Appendix F: one for the teacher
4. Clear glass: one for every student or group of students
5. Water
6. Oil: same amount as the water
7. Measuring cup: one for every student or group of students
8. Straw or pencil: one for every student or group of students
9. Optional: Ray Box for every student for optional activity on Appendix K

C. *Key Vocabulary*
1. *Refraction* occurs when light is bent. This happens when it is passes through a transparent or semi-transparent object.

2. A l*ens* is a piece of transparent glass that forms an image by refracting and focusing light that passes through it.
3. *Optics* are instruments that use lenses. Examples include eyeglasses, microscopes, etc.

D. *Procedures/Activities*
1. Review Lesson Two with the students.
2. Review the two ways that students have learned about how light can be controlled (blocking it and reflecting it).
3. Tell the students that today they will learn a third way to control light.
4. Ask the students, "Have you ever put your legs in a pool and noticed that they looked bent or distorted?" Have the students tell of other times when their images, or other objects, have appeared distorted or unreal. Tell the students that in the experiment for this lesson they will learn why that happens.
5. Tell the students that the question today is "Why do objects appear to be bent when placed in water, or other transparent objects?" Have the students write this question in Appendix C. Then have them write down their hypothesis to the question.
6. Have the students perform the first experiment from Appendix F.
7. Have the students share their conclusions with the class. Explain to the students that as light passes through transparent objects it slows down and bends. The speed that light travels depends on the density of the object it is passing through. It is traveling through the water at a different speed than air and at a different speed then the oil. Therefore, it bends each time and makes the object appear to be bending as well. This is called refraction.
8. Explain to the students that the glass is used as a lens to help make the pencil or straw look bent.
9. Tell the students that the question for the second experiment is "What will happen when light passes through concave and convex lenses?" Have the students develop a hypothesis. They should be able to determine that the light will bend, but try to get them to focus on the shape of the lenses.
10. Before starting the experiment, go over the vocabulary words with the students. Have them complete the vocabulary page on Appendix B now or at the end of the lesson.
11. Have the students perform the second experiment and record their results.
12. Discuss the results of the experiment and the conclusions that students have made.
13. Tell students that they will discuss in further detail how lenses and light are used to make our lives better in a later lesson.

E. *Assessment/Evaluation*
1. Students will be assessed on their oral answers to the review questions for previous lessons.
2. Students will be assessed on their understanding of refraction and lenses by their conclusions to the two experiments in Appendix F.

Lesson Four: Prisms and Rainbows (approximately 45 minutes)

A. *Daily Objectives*
1. Concept Objective(s)
   a. Students understand the processes of scientific investigation and design, conduct, communicate about, and evaluate such investigations.
   b. Students know that energy appears in different forms, and can move (be transferred) and change (be transformed).

2. Lesson Content
    a. The spectrum: use a prism to demonstrate that white light is made up of a spectrum of colors.
3. Skill Objective(s)
    a. The students will conduct an experiment to show that white light is made up of a spectrum of colors.
    b. The students will learn the spectrum of colors by using the acronym ROY G BIV.

B. *Materials*
1. Appendix B: students should already have this from previous experiments
2. Appendix C: one per student
3. Appendix G: one for the teacher
4. Prism
5. Flashlight, sunlight, or transparency projector
6. Two pieces of cardboard
7. Glass container of water
8. *The Magic School Bus Makes a Rainbow*

C. *Key Vocabulary*
1. The s*pectrum* is the colored light that is produced when white light is separated by a prism.
2. A p*rism* is a transparent object, usually made of glass, which is used to separate white light into the spectrum of colors.

D. *Procedures/Activities*
1. Review with the students the three ways that they learned of controlling light (blocking, reflecting, and refracting).
2. Ask the students the question, "What color is light?"
3. Turn on the beam of a flashlight and have the students tell you what color the light looks like. They should say white.
4. Tell them that light is actually not white.
5. Have them write on the recording sheet in Appendix C the question, "What color is light?" Allow them time to write a hypothesis.
6. Perform the experiments in Appendix G.
7. Students should conclude that white light is actually made up of many colors.
8. Go over the vocabulary words with the students. Discuss how the prism bends the light into separate colors.
9. Ask the students to give ideas as to why a rainbow is formed. Discuss. (A rainbow is formed when light travels through raindrops. The raindrops act like a prism to separate the light into a spectrum of colors.
10. Tell the students that they can remember the colors that make up the rainbow (some of the colors of white light) by remembering ROY G BIV. Each letter represents a color of the rainbow.
11. Optional: Read the book *The Magic School Bus Makes a Rainbow*.

E. *Assessment/Evaluation*
1. Students will be assessed orally for their responses to review questions from previous lessons.
2. Students will be assessed on their understanding that white light is made up of a spectrum of colors by the conclusion they draw when performing a prism experiment.

Lesson Five: Lighting up the world with mirrors and lenses (approximately 45 minutes)

A. *Daily Objectives*
   1. Concept Objective(s)
      a. Students understand the processes of scientific investigation and design, conduct, communicate about, and evaluate such investigations.
      b. Students know that energy appears in different forms, and can move (be transferred) and change (be transformed).
   2. Lesson Content
      a. Reflection
         i. Uses of mirrors in telescopes and some microscopes
      b. Lenses can be used for magnifying and bending light (as in magnifying glass, microscopes, camera, telescope, binoculars).
   3. Skill Objective(s)
      a. Students will identify different optical instruments that use lenses and mirrors to control light and the uses of the instruments.

B. *Materials*
   1. Pictures of different optical instruments
   2. Optional: various optical instruments

C. *Key Vocabulary*
   None

D. *Procedures/Activities*
   1. Review the concepts in the above lessons.
   2. Tell the students that both mirrors and lenses are used in instruments that people use to study other aspects of nature.
   3. Have the students name different instruments that they can think of that use mirrors or lenses.
   4. Show pictures of some of these instruments.
   5. Have the students tell you what these instruments do and discuss ways that these instruments use mirrors and lenses.
   6. Have the students get into groups of three to five students. Using the list of instruments that they generated, have the teams race against each other to name the most professions to use each instrument. Set a time for about five minutes (or however long you want). When time is up, have each group share their lists. The group with the most valid professions wins.
   7. Optional: If there is extra time, allow students to briefly research how these instruments use lenses and mirrors.

E. *Assessment/Evaluation*
   1. Students will be informally assessed on their answers to the functions of each instrument and the professions that use the instruments.

VI. CULMINATING ACTIVITY

A. Administer the test in Appendix H.

B. Have a mini "light science" day. Allow the students to develop their own experiments with light. Have them come up with their own question, hypothesis, method of testing the hypothesis, results and conclusion. Have the students share their experiments, results and conclusions with the rest of the class.

VII. HANDOUTS/WORKSHEETS

A. Appendix A: Scientific Method for Students
B. Appendix B: Vocabulary Page
C. Appendix C: Experiment Record Page

D. Appendix D: Shadows Experiment
E. Appendix E: Reflection Experiment
F. Appendix F: Refraction Experiment
G. Appendix G: The Colors of White Light
H. Appendix H: Light Test
I. Appendix I: Light Test Answer Key
J. Appendix J: Grading Standards
K. Appendix K: Extension Activities

VIII. BIBLIOGRAPHY

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Appendix A

Scientific Method for Students

Step 1: Question or problem

The question or problem is basically what the experiment is about. It is the question that will be answered or the problem that will be solved in the experiment.

Step 2: Hypothesis

The hypothesis is what you think the outcome will be. In other words, what will be the answer to the question or solution to the problem? This is an educated guess based on what you know and have already observed.

Step 3: Procedure

The procedure is the actual experiment or how you are going to prove or disprove the hypothesis.

Step 4: Results/Data

The results or data are the outcome of the experiment. What happened when you followed the procedure?

Step 5: Conclusion

Based on the results of the experiment, what conclusions can you draw? Was your question answered or your problem solved? Is your hypothesis correct?

Vocabulary Page

Word: Opaque **Part of speech:**	**Definition:**
Illustration of the vocabulary word:	
Use the word in a sentence:	

Word: Optics **Part of speech:**	**Definition:**
Illustration of the vocabulary word:	
Use the word in a sentence:	

Word: Reflection **Part of speech:**	**Definition:**
Illustration of the vocabulary word:	
Use the word in a sentence:	

Vocabulary Page

Word: Mirror **Part of speech:**	**Definition:**
Illustration of the vocabulary word:	
Use the word in a sentence:	

Word: Plane Mirror **Part of speech:**	**Definition:**
Illustration of the vocabulary word:	
Use the word in a sentence:	

Word: Concave **Part of speech:**	**Definition:**
Illustration of the vocabulary word:	
Use the word in a sentence:	

Vocabulary Page

Word: Convex **Part of speech:**	**Definition:**
Illustration of the vocabulary word:	
Use the word in a sentence:	

Word: Refraction **Part of speech:**	**Definition:**
Illustration of the vocabulary word:	
Use the word in a sentence:	

Word: Lens **Part of speech:**	**Definition:**
Illustration of the vocabulary word:	
Use the word in a sentence:	

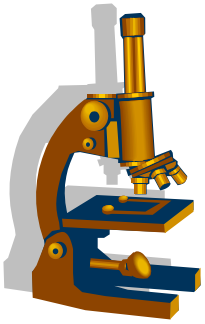
Vocabulary Page

Word: Spectrum **Part of speech:**	**Definition:**
Illustration of the vocabulary word:	
Use the word in a sentence:	

Word: Prism **Part of speech:**	**Definition:**
Illustration of the vocabulary word:	
Use the word in a sentence:	

Appendix C

Experiment Record Page



Question

Hypothesis

Procedure

Results

Conclusion

Appendix D

Shadows Experiment *

Purpose:
In this experiment students will come to the conclusion that shadows are formed when opaque objects block the path of light rays.

Materials:
Butcher paper -- enough for each student
Flashlights, light bulbs, and/or a transparency projector
Pencils
White paper
Students

Procedure:
1. Ask the question, "What happens when an opaque object blocks the path of light?" Tell the students to write down their hypothesis for this experiment.
2. With the room as dark as possible, shine a light source on a wall. If you are using a transparency projector you can just turn it on.
3. Have one student choose an opaque object and block the light source. Discuss what happens with the students. Allow other students to do the same thing. The students should come to the conclusion that opaque objects form shadows when they block the path of light rays.

Assignment:
1. Have the students break into pairs of three.
2. Using a flashlight, have one student sit or stand sideways near a wall.
3. Tape a sheet of paper to the wall behind the student.
4. Have one person shine a flashlight so that the other student's head casts a shadow on the paper.
5. Then have the third student draw around the edge of the shadow.
6. Have the students switch roles until all students have a shadow portrait of themselves. (This also can be done using the transparency projector and some parent volunteers.)
7. After the students cut out their shadow portraits, give them the choice of writing a paragraph, poem, or short story on the portrait about how their shadow came about. Encourage them to be creative, but to also include the scientific reason for what happened in this experiment.

*Shadow experiments and extensions adapted from experiments located in *Seeing is Not Believing* (see bibliography).

Appendix E

Reflection Experiments*

Purpose:
Students will learn that light is reflected at different angles and in different ways depending on the shape of the mirror.

Materials (provide enough of the following for each group of students to have one):
Plane (flat) mirror
Flashlight
White paper or poster
Spoon

Plane Mirror Reflection Procedure:
1. Break the students into groups of about three students. Each group should have one of each of the materials listed above.
2. One student should hold the mirror up against the white paper or poster at a right angle.
3. Another student will shine the flashlight on the mirror.
4. The third student should trace a pencil along the path of the two light paths.
5. They should then make observations on their students experiment page.
6. Allow the students to try different angles and make observations.

Convex Mirror Reflection Procedure:
1. Students should stay in the same groups.
2. Show the students the convex side of the spoon. Tell them to look at their reflections on the convex side of the spoon.
3. Ask, what does your image look like? (Magnified image of what you would see in a regular mirror.

Concave Mirror Reflection Procedure:
1. Direct students to look at their reflections on the concave side of the spoon.
2. Ask, "What is different about your image on this side of the spoon?" (It is upside down)

Tell the students that they would need a larger concave mirror to see their reflections right side up. Have the students give reasons for this.
Discuss how light is reflected off of objects at certain angles and produce an image. So, when you look at yourself in a mirror, you are seeing an image that is the result of light bouncing off of the mirror and reflecting your image.

*The experiments in this lesson were adapted from experiments in *The Optics Book* (see bibliography).

Appendix F

Refraction Experiments

Bent Pencil Experiment*

Purpose: Students will learn that when light passes through transparent objects it is bent and slightly distorts the image of other objects.

Materials (enough for each student or each group of students):
Clear glass
Water
Oil – same amount as the water
Measuring cup to make sure the water and oil are the same.
Straw or pencil

Procedure:
Students may do this experiment individually, in groups, or as a class depending on the amount of materials available.

1. Pour some water into the glass using the measuring cup.
2. Put the straw or pencil in the water at an angle.
3. Look at the straw or pencil and notice that it seems bent.
4. Using the measuring cup, pour the same amount of oil as water in the glass. It will form layer.
5. Notice how the straw/pencil appears bent in two different places now.

Concave and Convex Lens Experiment

Materials:
Concave lens – such as an eyeglass lens
Convex lens – such as a magnifying glass
A printed piece of paper such as a book page

Procedure:

1. Place the convex lens on top of the printed paper. Notice the size and direction of the print.
2. Move the lens away from the paper and notice that the letters look larger and right-side up. As you move the lens closer to your eye, though, the image becomes blurry.
3. Then, move the lens until the letters disappear and then reappear. The letters are now upside down.
4. Now try the same thing with the concave lens. The concave lens gives a smaller, right-side up virtual image of the page no matter where you move it.

*adapted from *The Optics Book* and "Refraction Activity" website (see bibliography).

Appendix G

The Color of White Light

Purpose:
The students will understand that white light is actually made up of a spectrum of colors.

Experiment #1

Materials:
Prisms: enough for the students
White poster or wall
Sunlight or transparency light or a flashlight

Procedure:
1. Have the students hold a prism up to the sunlight, flashlight, or transparency light.
2. The students should see a rainbow on the wall or white poster board as the light goes through prism. Discuss the colors that the students see.

Experiment #2

Materials:
A round container of water
Flashlight
Two pieces of cardboard

Procedures:
1. Cut a small hole in the middle of one piece of cardboard. Tape the cardboard to the flashlight so that only a small hole of light shines through.
2. Cut a larger hole (about the size of a fist) in the middle of the second piece of cardboard.
3. Hold the second piece of cardboard up near the container of water. Shine the flashlight through the hole in the cardboard and toward the water. A rainbow should show up on the cardboard.

Appendix H

Light Test

Match the following words with their definitions.

____	Refraction	A. colored light that makes up white light
____	Prism	B. a piece of transparent glass that forms an image by refracting and focusing light that passes through it.
____	Spectrum	C. a transparent object, usually made of glass and triangular, that is used to separate white light into the spectrum of colors.
____	Optics	D. a flat mirror
____	Lens	E. instruments that use lenses. Also, the study of light.
____	Concave	F. curved outward
____	Convex	G. curved inward
____	Plane Mirror	H. the process of bending light

Short Answer:

1. What happens when light is reflected? What object best reflects light?

_____

_____

_____

2. Explain what happens to light when it is refracted. What type of object is used when light is refracted?

_____

_____

_____

3. What happens when light is blocked by an opaque object?

_____

_____

4. Name at least three instruments that use lenses or mirror to bend and reflect light.

_____

_____

_____

Appendix I

Light Test Answer Key

Match the following words with their definitions. (Give one point for each correct answer).

__H__ Refraction	A. colored light that makes up white light
__C__ Prism	B. a transparent object that refracts and focuses light when it passes through it.
__A__ Spectrum	C. a transparent object that is used to separate white light into the spectrum of colors.
__E__ Optics	D. a flat mirror
__B__ Lens	E. instruments that use lenses. Also, the study of light.
__G__ Concave	F. curved outward
__F__ Convex	G. curved inward
__S__ Plane Mirror	H. the process of bending light

Short Answer:

1. What happens when light is reflected? What object best reflects light? **(two points**)
   Student answers should include that when light hits an object it bounces off the object to show an image or reflection. They should indicate that the best object to reflect the object would be a mirror.

2. Explain what happens to light when it is refracted. What type of object is used when light is refracted? (two points)
   Student answers should indicate that light is bent when it is refracted. A transparent object or a lens is used to refract light.

3. What happens when light is blocked by an opaque object? **(one point)**
   When light is blocked by an opaque object, a shadow is formed.

4. Name at least three instruments that use lenses or mirror to bend and reflect light. **(one point total if three or more are named)**
   Allow any reasonable answer.

Appendix J

Grading Standards

Experiments

	4-Above Proficiency	3-High Proficiency	2-Low Proficiency	1-Below Proficient
Teamwork and Directions	The student worked well with others in his/her team and partners to conduct experiments. Students followed directions and recorded the information correctly.	The student worked fairly well with others in his/her team. The student mostly followed directions. The student recorded information correctly.	The student had some difficulties working with others in their group. The student did not follow some directions well or recorded some information incorrectly.	The student did not work well with his/her team. The student did not follow directions well, recorded information incorrectly, or did not record the information at all.
Hypothesis and Conclusion	The student's hypotheses were well thought-out and his/her conclusions based on the experiments were correct.	The students hypotheses were mostly well though-out and conclusions were mostly correct.	The student did not put much effort into his/her hypotheses. The student's conclusions were mostly incorrect or little effort was put into recording them accurately.	The students did not attempt to think through his/her hypotheses. The student's conclusions were inaccurate or he/she did not record any conclusions.

Vocabulary Page

Word: **Part of speech:** ***(Give one point if the student gives the accurate part of speech for the word.)***	**Definition:** ***(Give one point for a definition that correctly explains the meaning of the word)***
Illustration of the vocabulary word: ***(Give two points for an illustration that accurately and neatly shows the meaning of the word. Give one point if the illustration only shows an adequate understanding of the meaning of the word.)***	
Use the word in a sentence: ***(Give one point if the word is used correctly in a sentence.)***	

Extension Activities

Ray Box

A ray box is used by scientists to study the behavior of light when it is either reflected by a mirror, or refracted by a lens. Students can make a ray box that will help them be more accurate in some of their experiments. This will take some time and materials, but can be a useful tool for almost all of the lessons in this unit. This experiment is adapted from *The Optics Book* (see bibliography). Here's how to make one:

Materials:
Large shoebox with a lid
Scissors
A piece of cardboard measuring about 4x5 inches
Masking tape
Small flashlight

Cut a hole in the short side of a shoebox starting at the bottom. Cut a rectangle from the piece of cardboard that is about 1 inch larger than the hole in the shoebox. Make three slits about ½ inch apart in the cardboard. The slits should be just wide enough to let some light through. The slitted rectangle is called a baffle. Tape the baffle over the hole in the shoebox with the slits touching the bottom edge of the box. Tape the flashlight into the cardboard box on the opposite short side as the baffle. The light from the flashlight should be directed towards the baffle. Close the box lid. Turn off the classroom light and turn on the flashlight. Observe the behavior of the light coming through the slits. Then try making another baffle with five slits instead of three and one with only one slit. When the flashlight is positioned correctly, you should see that the light shines in a straight line.

Shadows (Opaque materials):

Fun Extension: Give students time to make animal shadows on the wall. Allow them to also try these shadows on other surfaces such as desks, the floor, or outside on concrete or grass. Discuss how these shadows are different or the same.

Homework Extension #1: Have the students take a "light walk" with an adult. During this walk they should observe various shadows formed by objects in nature. For example, what kinds of shadows do leaves form? Are they all the same? The students should record their observations and conclusions in a notebook.

Homework Extension #2: Have the students make a shadow clock. Here's how: Stand a pencil or stick in a thread spool. Use glue or clay to fix the spool to the piece of white paper. On a sunny day, put the shadow clock outdoors where the sun will shine on it. Draw a line along the

shadow of the stick and write the time at the end of the line. For accurate results, do this every 15 minutes. Discuss with the students how this is a simple form of a sundial, which was invented more than 3,000 years ago, before clocks and watches were made.
Note—this can also be done as a class project.

Technology Extension:
Take a "Light Walk" with Bob Miller. Bob Miller is an artist who studies the patterns of light. Go to his website at www.exploratorium.edu/light_walk/lw_main.html. Here students can learn more about shadows, see images using shadows and light, here Bob Miller talk about some of his observations and conclusions, and do more activities including a making a pinhole camera.

Reflection (Mirrors):

Extension of mirror and spoon experiment:
Allow the students to try other opaque objects to determine which surfaces reflect light the best.

Mirror extension:
Have the students write their name and hold it up to the mirror. Tell them to make observation about what is different about their names. Talk about how mirrors do not reflect an exact image. Have the students write a mystery message that can only be read when held up to the mirror.

Homework extension: Have the students make their own mirrors by taking a piece of aluminum foil, smoothing it out, then gluing it onto some cardboard. Have them write observations about what is different about their homemade mirror.

Technology extension: After having the students make their own mirrors, have them research on the internet how a real mirror is made and make observations about why it would be harder for them to see their images in the homemade mirror than in a store-bought mirror.

Multiple mirror extension: Using the ray box or a simple flashlight, have the students set up two or more mirrors to try and create their own reflection path.

Refraction (transparent materials):

Ray Box experiment: Find a transparent concave lens and convex lens. Using the ray box, shine the light through a concave lens. Have the students give observations on how the light is bent. Then shine the light through a convex lens and have the students do the same thing. The concave lens should bend the light out. The convex lens should bend the light in.

Rainbow

Ray Box experiment: Use the Ray Box to shine a light through a prism. Allow the students to record their observations.