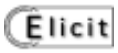
Facilitator's Guide

Grade: 5
Unit: Light Energy
Title: Refraction

Topic:	Refraction of Light
Lesson Summary:	The purpose of this lesson is for students to explore the effect of light passing through different mediums to discover that light can be treated as if it travels in a straight line. It may appear to detour, but those detours are mostly straight lines.
Arkansas Frameworks:	http://www.arkansased.org/teachers/word/science_k-8_011006.doc
Science Standards	PS.7.5.1 Summarize how light can interact with matter through absorption, refraction, and reflection. PS.7.5.2 Investigate how light travels and interacts with an object or material. PS.7.5.3 Conduct investigations demonstrating how an object can be seen. PS.7.5.4 Design and conduct investigations of transparent, translucent, and opaque. NS.1.5.1 Make accurate observations. NS.1.5.2 Identify and define components of experimental design used to produce empirical evidence: hypothesis, replication, ample size, appropriate use of control, use of standardized variables. NS.1.5.4 Interpret scientific data using: data table/charts, bar graphs, circle graphs, line graphs, stem-and-leaf plots and Venn diagrams. NS.1.5.5 Communicate results and conclusions of the scientific inquiry.
Math Integration	DAP.15.5.1 Interpret graphs such as line graphs, double bar graphs, and circle graphs. DAP.16.5.1 Make predictions and justify conclusions based on data. DAP.17.5.1 Identify and predict the probability of events within a simple experiment. DAP.14.5.2 Collect numerical and categorical data using surveys, observations and experiments that would result in bar graphs, line graphs, line plots and stem-and-leaf plots. DAP.14.5.3 Construct and interpret frequency tables, charts, line plots, stem-and-leaf plots and bar graphs.
Literacy Integration	OV.3.5.1 View a variety of media (e.g., posters, film clips, periodicals, charts, cartoons, etc.) to enhance and show understanding of a specific topic. OV.3.5.3 Use visual aids to convey information. W.4.5.2 Organize ideas by using such graphic organizers as webbing, mapping, and formal outlining with main topics. IR.12.5.4 Gather information from a source appropriate to purpose and topic.
National Frameworks: Science Standards	**Science as Inquiry** Demonstrate abilities necessary to do scientific inquiry. 1. Use appropriate tools and techniques to gather, analyze, and interpret data. 2. Develop descriptions, explanations, predictions, and models using evidence. 3. Think critically and logically to make the relationships between evidence and explanations. 4. Communicate scientific procedures and explanations. **Physical Science** 1. Document that light can be treated as if it travels in a straight line until it strikes an object. Light can be reflected by a mirror, refracted by a lens, or absorbed by the object; and 2. Document that light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). An object is only seen if it emits or scatters light. **Science and Technology** 1. Demonstrate abilities of technological design. 2. Implement a proposed design. 3. Evaluate completed technological designs or products.
Objectives:	Students will investigate, demonstrate and explain refraction as it applies to light.

Focus Question:	How does light interact with matter?
Background Information:	Light is a form of energy that is visible to the human eye and is common in our everyday lives. Light can be treated as if it travels in a straight line through transparent materials such as air, water, glass, or clear plastic. A ray of light will continue until it interacts with an object. At that time, the ray of light will be absorbed, reflected or refracted. A narrow beam of light aimed at a mirrored surface will provide examples of reflection. An object such as a pencil or straw in a clear glass of water will provide evidence of refraction. When the light passes through the glass, the light changes speed. The light changes speed again when it enters the water. Therefore, the eye assumes no refraction has taken place only a change in the placement of the object. In addition, a rainbow provides evidence of refraction. Light passes through a prism (a collection of raindrops can be a prism) and white light is bent/separated to reveal the visible colors of the spectrum. The visible spectrum is white light and includes red, orange, yellow, green, cyan and violet. ROYGBIV is no longer used as a mnemonic dev indigo is no longer included. In the 1700's, what we call blue was called indigo. So, real colors of the rainbow are red, orange, yellow, green, cyan and violet. Cyan has replaced the "old" blue.
Essential Vocabulary	**reflect -** change in the direction of a light ray as it bounces off an object (ADE Framework) **refract -** bending of a light ray when it passes at an angle from one substance into another substance in which its speed is different (such as when light passes through air into water) (ADE Framework) **light ray -** narrow beam of light **transmission** - the fraction of light energy that passes through a substance **converge** - to come together **diverge** - to move apart **parallel** - lines that are equal distance apart and never intersect **non-parallel** - lines that are an unequal distance from each other and will intersect at some point **prism** - optical triangular shape device made of glass or quartz and used to seperate a light beam into the different colors of the spectrum or invert an image **concave lens** - lens which curves inward and causes light rays to spread apart or diverge **convex lens** - curves outward or bulges outward, causes light rays to meet or converge

Timeline:	This lesson should take two to three 50 minute periods of time to complete.	
	Instruction	**Facilitator's Notes**
Materials:	***Elicit / Engage – Laser Ice*** • Glass of ice • Laser ***Engage – Lights and Prisms*** • Narrow beam of light from light box • Paper on the table top • Pencil • Rectangular plastic box (to use as a prism) • Water • Milk or non-dairy creamer • Stir sticks • Convex lens • Concave lens • 2 small screens made from white poster board ***Explain – Bending Light*** • Tall clear glass • Straw, glass rod, or pencil	

	Elaborate - Blue Sky • A transparent plastic box, or a large beaker, jar, or aquarium • A flashlight or projector (either a slide or filmstrip projector) • Powdered milk • Polarizing filter (such as the lens from an old pair of polarized sunglasses) • Blank white card for image screen ***Evaluate*** - Student lab notebooks ***Extend – Glue Stick Sunset*** • Mini-MagLite or penlight • 4 to 6 glue sticks (clear ones used in glue guns) • White background (paper, wall, or cloth) • Clear packaging tape • Two polarizing filters ***Open Explore with the Lightbox*** • lightbox • mirrors • lenses (concave and convex) • Blank white card for image screen	
	1. **Laser lights, Sunlight, Flashlights, or Maglites** - looking directly into the light or pointing the light in the eye can cause serious permanent damage to the retina. Only the teacher should use the laser light during the experiments. 2. **Hairspray** - be sure to aim the can away from face and eyes. Goggles should be used for young children. 3. **Light bulbs** - heat generated by the bulbs can cause serious burns / bulbs made of glass can break and cut the skin or eyes (especially halogens) / salt and oils from bare hands can cause bulbs to shatter when turned on. 4. **Mirrors** - be aware of sharp edges 5. **Lenses and Mirrors** - can magnify the intensity of the light. Teacher should monitor students carefully to avoid reflection into someone's eyes or causing heat which will burn. 6. **Batteries** - should not be installed backwards, put in fire, or mixed with other battery types. This may cause exploding or leaking. 7. **Broken bulbs or old batteries** - should be handled by the teacher and not the student. 8. **Disposal of bulbs or batteries** - wrap glass bulbs before throwing them away / recycle batteries in the proper place (The local post office may have a battery recycling box). 9. **Eating** should be avoided in the science lab area. 10. **Arrange room** and put away unneeded items to avoid tripping and allow for free movement of students during the experiences that require the room to be dark.	
Facilitator Preparation:	1. Fold three index cards in half and punch a hole through all of the cards so the holes can be lined up when set on a table. Fold one other card in half. This will make one set of cards. You will need one set per group of students. 2. Set up Light Boxes and lenses.	Hint: place each set of cards into a zip-lock bag for easy distribution, collection, and storage.
 	***Straight Shooter*** How does light travel? 1. Each group of students needs a set of prepared index cards, and a flashlight. 2. Ask students to experiment with the placement of the cards to determine a way to get a light ray to pass through all the cards and stop at the 4th card. 3. Have groups leave their cards set up. 4. Allow the groups to move around the room to view other configurations	To ensure that participants get a grasp of the fact that light travels in a straight line but can take detours do both of these activities to begin this session. Discuss with the students how the light traveled. Does light travel in a straight line? How do you know?

	Laser Ice - Demonstration 1. Set a glass of ice on the table. 2. Shine a laser though the ice. 3. Have the students complete the Pre-Lesson part of a Reflection Log page in the Science Lab Book. The open ended question will be the FOCUS QUESTION for this lesson.	When students have demonstrated an understanding that light travels in a straight line then do the demonstration with the laser and the ice. Option: Show the glass of ice and laser on a document camera. NO WATER IN THE CUP OF ICE.
	Is It Real or an Illusion? Pencil in a Glass How does light change as it goes from a less dense medium to a more dense medium? Procedure 1. Complete the pre-lesson part of the Reflection Log using the question, "How does light change as it goes from a less dense medium to a more dense medium?" 2. Fill a clear glass ¾ full of water. 3. Place a pencil into the glass of water. 4. Observe the pencil from the side of the glass. 5. Draw and describe what the pencil looks like ABOVE, BELOW, and AT the water line. 6. Provide reasons for what is going on. 7. Add ½ to 1 inch of oil to the cup of water. 8. Describe what happens. 9. Draw and describe what the pencil looks like ABOVE, BELOW, and AT the water/oil line. 10. Complete the post-lesson part of the Reflection Log.	Due to time limitations you can just demonstrate the Lights and Prisms - Bending Light. Take a few minutes (maybe 15) to do the Lights and Prisms - Colors. Because of time constraints you probably don't want to do the Reflection Log here. Light changes directions when it goes from one medium to another. This lab demonstrates light traveling (refracting) through parallel surfaces. As white light travels through non-parallel surfaces it is separated revealing the colors of the spectrum.
	Lights and Prisms - Colors Procedure 1. Complete the pre-lesson part of the Reflection Log using the question, "What colors can be produced by scattering white light?". 2. Fill the rectangular prism box about ½ full with water. 3. Position the prism box on the white paper so that you can see a beam of light traveling through it. 4. Shine the light so it enters the prism box to get a rainbow. 5. Turn the prism box to get the critical angle (The light stays in the box. Fiber optics is an example). 6. Move the prism box back to get the rainbow. 7. Describe which color bent the most. 8. Draw the prism box; the light; and the rainbow; label all the visible colors of light. 9. Complete the post-lesson part of the Reflection Log.	**Lights and Prisms - Colors** As light travels through materials colors can be produced when the light scatters. What colors can be produced by scattering white light?

Explore Inquiry	***Lights and Prisms: Rainbows*** How can white light be separated and put back together again? 1. Complete the pre-lesson part of the Reflection Log using the question, "How can white light be separated and put back together?" 2. Fill the rectangular prism box ½ full with water. 3. Position the prism box on the white paper so that you can see a beam of light traveling though the prism. 4. Shine the light so the light enters the prism box and produces a rainbow. 5. Place the lens filled with water in the path of the rainbow. 6. Place the lens so colors converge at one point. 7. Place screen where the light comes back together at one point (converges). (Screen 1 in diagram below) 8. Place screen 2 as shown in the diagram on the student page. 9. What do you notice about the colors in the rainbows on screen 2. 10. Complete the post-lesson part of the Reflection Log.	This part of the lesson should go well right after the Lights Prisms - Colors as you are already set up. You may want to skip the Reflection Log again. This lab demonstrates the splitting of white light and putting the colors back together. Diverging beams on screens can produce rainbows. Converging the rainbow puts the colors back together.
Explain Inquiry	***Lights and Prisms: Angles of Light*** How does the light ray entering a prism compare to light ray leaving the opposite side of the prism? Procedure 1. Complete the pre-lesson part of the Reflection Log using the question: "How does the light ray entering a prism compare to light ray leaving the opposite side of the prism?" 2. Fill the rectangular prism box about ½ full with water 3. Add a small amount of milk or non-dairy creamer to the water to make it slightly less transparent. This will make it easier to see the light. 4. Position the prism on the white paper so that you can see a beam of light traveling through it. 5. Shine the light so it enters the box on one side and exits on the OPPOSITE side. 6. With the pencil, trace the box, and the three "lines" of light on the paper. 7. Notice the light inside the box as you look down on the top of the box. 8. Does it line up with the light beams you see on the paper underneath it? 9. Remove the box from the paper. 10. Using the pencil, connect the "lines of light where the box used to be. 11. Notice that the light was bent twice, once at each boundary. The light coming out of the far side of the box is parallel to the incoming light. 12. OPTIONAL: Measure the angle of incidence and reflection. 13. Complete the post-lesson part of the Reflection Log	Does light actually "bend"? Light "bends" when it moves from one transparent material to another (from air into water for example). The greater the density between the two materials the more the light will "bend". Bending light is called, "refraction". Refraction is used to create many illusions because we see a change in the object from which the light is coming, but we do not see the "bending" of the light.

Elaborate Inquiry	**Blue Sky** You can create a model of a blue sky. Why is the sky blue and the sunset yellow-orange? 1. Complete the pre-lesson part of the Reflection Log using the question, "Why is the sky blue and the sunset yellow-orange.?" 2. Fill the container ¾ full of water. 3. Place the light source so that the beam shines through the container. 4. Add powdered milk – a pinch at a time. Stir until you can clearly see the beam of light. 5. Observe the beam from the side of the container and then from the end of the container. 6. Let the light project onto a white card that you hold at the opposite end of the container from the light source. 7. Describe what the light looks like on the card at the end of the container. 8. Let the project onto a white card that you hold at the side of the container. 9. Describe what the light looks like on the card at the side of the container. 10. Complete the post-lesson part of the Reflection Log.	This Lab models why the sky is blue and the sunset is red. http://www.exploratorium.edu/snacks/blue_sky/indx.html When sunlight travels through the atmosphere, blue light scatters more than the other colors causing the sky to look blue. The light that continues to travel (is transmitted) through the atmosphere leaves a dominant yellow-orange hue which causes the sky to look reddish-orange (sunsets).
Evaluate High-Yield Strategies	***Science Lab Book*** Post-Lesson of ***Reflection Log*** started in the Elicit part of the lesson and any ***Experiment Log*** pages. ***Science Terms*** page to evaluate knowledge of terms covered in this lesson.	Do at least one page of the Science Terms so they know how to do them. You may choose to do all or only part of the vocabulary listed depending on the level of your students.
Extend Inquiry High-Yield Strategies	***Glue Stick Sunset*** 1. Shine the maglite into one end of a glue stick and hold the other end of the glue stick approximately one centimeter from the white background. 2. Notice that the end of the glue stick closer to the Mini-MagLite is a different color than the end nearer the white background. 3. Notice the color of the circle on the white background. 4. Place two glue sticks end to end, and attach them together with the clear tape. 5. Repeat the investigation with the Mini-MagLite. 6. Notice any difference in the colors along the glue sticks and in the colored circle on the white background. 7. Attach more glue sticks with the clear tape. 8. Notice the changes in color and intensity along the glue sticks and in the colored circle. 9. Place a polarizing filter between the Mini-MagLite and the first glue stick. 10.Turn the filter while one person views the glue stick from the top and another views it from the side. 11.Notice that when the top person sees a bright beam, the side person will see a dim beam, and vice-versa.	***Glue Stick Sunset*** The scattering of light by the atmosphere, which creates the blue sky and red sunsets, can be modeled in this activity. http://www.exploratorium.edu/snacks/glue_stick/index.html Students should add the results of their explorations in their Science Lab Book – Reflection Log. Scattering can polarize light.

 	Lights and Lenses Questions for students to answer: 1. Can you bend light around an object (pencil)? Explain why or why not. If you can bend light explain how. 2. Can you produce colors? If so what colors occur and why. 3. Can mirrors be used to increase the amount of color projected? Explain. 4. Can you place the lenses in combination to diverge and then converge the light source? Explain. 5. Can you change the size of an image using a lens? Explain. 6. Find other objects in the room that can be used as a lens (concave or convex). How do they compare to the lenses provided? 7. Draw diagrams showing what is happening when light travels through different lenses (angles of light rays). 8. What is the measurement of angles that are occurring? 9. Can you change the angles of light rays? What are the smallest and largest angles you can produce and how. 10. Does the angle change with the size or shape of the lens?	Students will use the light box to explore with concave and convex lenses. They will answer the questions by exploring different situations and add the results of their explorations in their Science Lab Book – Reflection Log.
Cross-Curricular Integrations:	Refer to Science Learning Guide	
	Light Box	
Resources:	These websites provide videos and additional information. http://www.teachersdomain.org/resource/lsps07.sci.phys.energy.lighttravel http://www.promotega.org/hgr07009/index.htm (site created by 5th graders) http://www.exploratorium.edu/snacks/bluesky/index.html http://www.exploratorium.edu/snacks/blue_sky/indx.html	
Notes:		
Document Links:	Straight Shooter Lights and Prisms - Bending Light? Lights and Prisms - Color Creation Bending Light Line Designs Blue Sky Science Lab Book - Reflection Log Page Science Lab Book - Experiment Log Page Science Lab Book - Science Terms Page Glue Stick Sunset Lights and Lenses	