



Image courtesy of CSULB Shark Lab [Reproduced with permission]



## Anchoring Phenomenon

Numerous reports suggest an increase in white shark encounters\* in the United States in recent years and the public is worried.



## Lesson Concept

Develop and use a model to explain the effect of object distortion at the surface of water due to refraction of light at the surface.



## Investigative Phenomenon

Researchers above water have a hard time estimating the precise position and size of a white shark under the water.



## Standards

Refer to Appendix 8.8 for NGSS, CCSS (ELA), and California ELD standards.

\*Encounters include sightings and census estimates, as well as physical interactions between humans and sharks.

## 8.8 Light, Which Way Does It Go?

### Storyline Link

In the previous series of lessons, students have explored various components of tracking devices including magnetic fields, use of waves, and digitized signals.

It is in this lesson that students build understanding of the Performance Expectation for MS-PS4-2 by understanding that light (the same wave type as radio waves) does not change direction if the light hits perpendicular to the interface, and that it does change direction if the light hits at an angle. This is done through the context of scientists being challenged in estimating the precise position of a white shark when attempting to attach a tag. Light changes speeds when it transitions between mediums (in this case, from air to water), distorting the perception of where the shark is located. Students mimic this using a skewer and a gummy candy in a bowl of water. Students discover that when light hits the water at an angle other than 90 degrees, it looks “bent” due to the change in speed therefore making it difficult to correctly perceive the position of a white shark’s location in the water. Students move on to more experimentation using lasers and objects of different densities and use patterns to identify cause and effect relationships that inform the development and modification of a model, based on evidence, to match what happens when a variable or component of a system is changed. Students apply this information to understand how aerial surveys of white sharks misreport shark size because light distorts our perception of objects.

In the next lesson, students will begin to understand one of the biggest revelations since tracking technology has been used to study white sharks—the tremendous impact humans have had on their population.

Throughout the lesson, a flag (▶) denotes formative assessment opportunities where you may change instruction in response to students’ level of understanding and making sense of phenomena.

### Time

135 minutes

Part I	45 minutes	Engage
Part II	45 minutes	Explore
Part III	45 minutes	Explain

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### Materials

#### Whole Class

- 8.8.R1: Tweet from the CSULB Shark Lab
- Shark Week: Shark Tagging Explained* video, <https://www.youtube.com/watch?v=0eye27apFp4>
- Light at a perpendicular interface* video, <https://www.youtube.com/watch?v=09AQL10bZr4&feature=youtu.be>
- Light at an angled interface* video, <https://www.youtube.com/watch?v=MX6PQF1knxQ&feature=youtu.be>
- San Clemente Sharks May 10, 2017* video, [https://www.youtube.com/watch?v=oM-Qg\\_Wy6c8](https://www.youtube.com/watch?v=oM-Qg_Wy6c8)

#### Per Group of 4

- Bowl (the larger the better)
- Small gummy fish or other small gummy candy
- Bamboo skewer
- Supply of water
- Laser (inexpensive ones can be found at a pet store—aka, cat lasers—or dollar store)
- Medium, such as a piece of glass or acrylic, or clear gelatin (See Advance Preparation for details.)
- Protractor
- Colored pencils
- Small clear cups (in case students ask to test water in Step 8)

#### Individual

- Science Notebook
- 8.1.H2: Scientist Communication Survival Kit (from Lesson 1: Shark Encounters)
- 8.1.H3: My Shark Encounter Claim Chart (from Lesson 1: Shark Encounters)
- 8.1.H4: Crosscutting Concepts for Middle School Students (from Lesson 1: Shark Encounters)
- 8.8.H1: Refraction Investigation

#### Teacher

None

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### Advance Preparation

1. Review videos prior to working with students. Be sure you are able to project video from the internet. (Steps 1, 10, and 12 of Procedure)
2. Assemble materials for gummy fish activity. (Step 3 of Procedure)
3. Duplicate **8.8.H1: Refraction Investigation** for students and prepare materials for the investigation. If you are unable to acquire a small piece of glass or acrylic for the activity, clear gelatin can be used but will need to be made in advance. Unflavored gelatin can be found in most grocery stores. Follow the recipe for “juice blox” substituting water where juice is called for and omitting the honey. (Step 8 of Procedure)
4. Prepare to project **8.8.R1: Tweet from the CSULB Shark Lab**. (Step 14 of Procedure)

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### Procedure

#### Part I

Engage (45 minutes)

*Develop a model of the effect of how light behaves when entering a new medium at an angle.*

1. Prompt a discussion with something like this: “We’ve spent a lot of time understanding REMUS, tags and waves, and even digitized signals, but I heard many of you ask a question that we haven’t resolved yet—how do scientists get a transmitter tag on a shark? You saw a video of getting the fitness tracker style device on a YOY white shark, but I overheard some of you wondering how this would work with adult sharks. I’m curious to know your thoughts on this, how would scientists do this?” Allow students to discuss and share out with the class. Some possible answers include the following:
  - › netting
  - › fishing (with a hook and lure)
  - › using a cage with bait
  - › pole (spear)
2. Show students the video, *Shark Week: Shark Tagging Explained*. Ask students to discuss how this method of tagging a white shark compares to the method seen in Lesson 8.6: Tags and Waves. Ask students to share their thoughts:
  - › Which method do you think works best for YOY or juvenile sharks? Why?
  - › Which method do you think works best for adult sharks? Why?

#### TEACHER NOTE

The method that students saw in Lesson 8.6: Tags and Waves—using a gill net to isolate a YOY white shark, about 4 feet, to place in a temporary hold for tagging—took place off Southern California, where YOY and Juvenile white sharks are common. Students may recall how two adults struggled to capture the young shark. The location of the 15-foot adult white shark tagged in this video was Año Nuevo, central California, an area frequented by adult white sharks (and a well known elephant seal colony).

3. Let students know that they are about to see what it’s like to try and tag a white shark by scaling down the scenario. Give each group of students a large bowl filled with water and ask them to place a gummy fish (or other small gummy candy) in the bottom of the bowl.

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4. Tell students that they will try to tag a fish and need to “spear the fish” in order to get the tag on it. Ask them how easy they think this might be and at what angle they think it would be the easiest to spear the fish.
5. Give each group of students a bamboo skewer and ask them to spear the fish while looking *straight down* at the fish (with their line of sight perpendicular to the water).
  - a. Tell students to use one fluid motion without hesitation. (At this angle, all groups should easily be able to spear the fish.)
  - b. Ask students to record observations in their Science Notebook along with an initial model showing what is happening.
  - c. ► After a few moments, ask a few students to share what they included in their model. If no students represented light, ask the class how they were able to “see” the fish, water, skewer, etc., and what they should include in their model to represent how we are able to see things.

### TEACHER NOTE

► Students have studied light throughout elementary school, beginning in first grade, but may need a few reminders about what they learned about light and how they might represent light in a model. If your students have not had this experience, consider allowing some time for them to plan and conduct a brief investigation of how they see objects and how light allows for objects to be seen.

6. Now ask students about the practicality of a scientist being able to spear a white shark perpendicular to the water. Ask students to describe what they saw in the video. Most students will comment that the scientist in the video was off to the side and looking from an angle.
  - a. Ask students to replicate this scenario by spearing the fish while looking *at an angle*, from the edge of the bowl (a more likely scenario if they were on a boat and trying to tag a shark). Have them place the bamboo skewer on the edge of the bowl and their eyes should also be at that level. Once again, in one fluid motion (no stopping or adjusting the skewer in mid-motion) spear the fish. (Students should find that they “overshoot” the fish even though they line everything up perfectly.)
  - b. Ask students to record new observations in their Science Notebook and build a second model or revise their initial model to account for this new information of what they think is happening to the light.

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- c. Ask students to include an explanation as to why they are able to spear the fish from directly above but not when looking at the fish from an angle. To help students as they think of an explanation, ask the following:
  - i. When the angle of light (directly above vs. angled) changes, how does that influence your perception of where the fish is located?
  - ii. What predictions can you make about phenomena, with confidence, based on this cause and effect relationship?
  - iii. What is your evidence for this?

### TEACHER NOTE

The larger the bowl and the smaller the candy, the more dramatic the effect of not being able to “spear the fish” is. Spearfishing from directly above is typically the angle that students think would be the easiest, and they are correct, but you can have a discussion about the practicality of being able to get directly above the fish, or white shark, in the real world.

7. Most students will draw a model showing light going only in one direction (many students draw this as going from the eye to the fish); in this case, students are not considering a source of light, nor that light also moves from the fish to the eye. Visit tables as students are working to probe their thinking. (This is probably more effective as a table discussion, rather than whole class, even if the majority of the class is struggling with this. Table discussions force more students to grapple with their thinking.)
  - a. ► For students considering only one direction, ask them to consider the source, where the light is coming from. (Many students will consider the sun or a light on a boat, etc.) Encourage them to edit their model to accurately represent this.
  - b. ► For students not considering that the eye ultimately receives light for us to see, ask, “What happens in order for us to see something?” (Students should recall that light enters the eye.) Ask where the light entering the eye, allowing us to see the fish, is coming from. Confirm that for us to see, the light also has to travel from the fish to your eye, and ask, “How can this be represented in the model?”
  - c. Next, ask students how their model accounts for the effect that the angle of the light has on how light travels from the air to under the water and under the water to the air. How does light travel from underwater to a person above or light from above water to a fish below? After the discussion, ask students to show this in their model.  
  
► For students struggling with the modeling process, suggest that they add a story of what is happening to accompany the work they are able to do (like a narrative). If able, encourage them to use this story to inspire ideas of things they can add to the model and vice versa.

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### Procedure

#### Part II

Explore (45 minutes)

*Analyze, interpret, and predict the effect of changing the incident angle as it transitions between mediums.*

8. Ask students to rest the skewer in the bowl, like one might place a straw in a glass, and to observe. Ask what they notice. (Students should comment that the skewer looks broken or bent.) Ask students to record their observations and questions they have about this in their Science Notebook. Give the class a couple of moments to share observations and questions.
  - a. To help answer student questions, ask students to describe exactly where the skewer appears bent; students should be able to identify the location as the boundary between air and water. Ask students to share what they remember as being different between air and water. (Some students might describe differences in the types of particles, but continue to solicit ideas until students describe differences between gas and liquid.)
  - b. Confirm that something must be happening to the light as it transitions between gas and liquid (different mediums) and how the angle of the observer makes a difference. Remind students that salt water and fresh water are different mediums, even though both are liquid. (Students may recall describing salt water as having more stuff, or being thicker, than freshwater, because of the salt.)
    - i. To do this, give students **8.8.H1: Refraction Investigation** and materials needed for the investigation (glass, acrylic, and/or gelatin, and laser, protractor, and colored pencils). Ask students to have a notebook or paper ready to “catch” laser light to prevent it from hitting faces (see safety tip in the teacher note below), giving students the opportunity to test different angles and different mediums (this time, a solid vs. gas/air or various solids if all three can be acquired) and investigate the angle that light hits the interfaces between the gas/solid and then solid/gas.
    - ii. Let students know their ultimate challenge is to use what they learn from the investigation(s) to predict the behavior of light. Direct students to use the On-Target column of Cause and Effect, **8.1.H4: Crosscutting Concepts for Middle School Students** (from Lesson 8.1: Shark Encounters), to help them with this challenge. Students should record observations (written and visual are fine) and sensemaking in their Science Notebook. Although **8.8.H1: Refraction Investigation** has students primarily working with pattern, moving on in their discussions to consider Cause and Effect will further help with sensemaking.

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- iii. As students work, encourage them to generate questions and to let you know if they need other materials (for example, students might ask to test water instead of a solid). If possible, make these materials available for student use after they have done the basic investigation with a solid. Be aware, however, that this would increase the complexity of the investigation, as a cup of water would bring in different variables: a rounded surface that the laser would interface with, and the transition of the laser through multiple mediums (glass, water, then glass again). Despite the complexity of the path the laser takes, this is a suitable accommodation for a motivated student, as they are only looking at the patterns that come with this.
- iv. When students have completed their investigations, have a class discussion to share observations and wonderings.

### TEACHER NOTE

While using glass and/or acrylic is an easy and clean medium for the students to investigate, the gelatin has novelty but is messy. If time allows and all three materials can be obtained, it can be beneficial for the students to explore and do the same sequencing with each material. This can open up deep conversations about the densities of the materials and how those densities change the angle of the refracted light because of the more dramatic changes in speed. The assessment boundary for 8th grade is for a qualitative understanding of how the light interacts with different mediums. While students are being asked to measure angles (quantitative data), this is only for comparison purposes and they are not being asked to use these in equations. Additionally, laser safety should be explained to students before lasers are distributed. The lasers should either be pointed down at the ground or through the material. They should never be pointed at another person and not turned on until they are used in the investigation. Avoid shining lasers at faces. Students can avoid this by not putting faces in the path of a laser and by placing paper behind an object that a laser is pointing at.

9. At this point, students should confirm that the light appears to bend at the interface of two mediums when entering at an angle; they can predict the path of light, but are wondering why. To help explain this and support student sensemaking, have students “be” the light and experience what happens at the light interface—experiencing it both perpendicularly and at an angle to allow them to fully understand why the light appears “bent” when it enters at an angle.
  - a. Line up students in rows of five to be a “wavefront of light.” Have them take a step as one group.
  - b. When they hit the imaginary interface between the two mediums, ask them what they think would happen when moving from air to a solid. How is air different from

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the solid? Most students should describe the solid having particles much closer together than the air. If this is true, what would happen to the light moving from air to solid where the particles get much tighter? (Students should recognize that the light will slow down. If they don't, a friendly game of Red Rover—with and without arm barriers, and noticing the speed of the approaching runner—might help them reach this conclusion.)

- c. Ask the students representing the wavefront of light to take a smaller step to represent the slower speed of the wave in a more dense medium.
10. Having students represent the wavefront of light for both an interface that is perpendicular (as they just modeled) and at an angle. (This is a way to support students who need to process in a different modality.) Show the video [Light at a perpendicular interface](#), (or continue to have students represent the wavefront instead), to illustrate that the students (“wavefront of light”) continue in a straight line even though they have entered a new medium. Show the video [Light at an angled interface](#), to illustrate that as the students enter the new medium they also slow down, but the students on the outside of the line continue to take large steps, while students on the inside take smaller steps. This results in the entire line, or wavefront of light, changing directions as they all enter the new medium, explaining the appearance of light “bending.” Here it can be clarified that the light doesn't bend, but is experiencing more slowing in one area, and less slowing in another. This activity also reveals that the light does not change direction if it hits perpendicular to the interface. An outside observer would not be able to tell that the light had slowed down because the light didn't change its direction.



### Procedure

#### Part III

Explain (45 minutes)

*Refine the model of the effect of changing the incident angle as it transitions between mediums.*

11. Ask students to record a few *aha's* in their Science Notebooks (students can do this as visual representations and/or written descriptions) and then go back to their original model in their Science Notebook and make revisions to show their new understanding of how light interacts as it transitions between mediums at different angles. Ask students to include a brief rationale of their model to explain a pattern in the effect (sometimes we can tag it, sometimes we can't), predicted by the cause (angle of entry), to explain the phenomena (difficulty estimating the precise position of the fish/shark).

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- a. As students work, ask the following:
  - i. What difficulties might a scientist have in tagging a white shark if they were to use a pole with a tag on the end to spear the shark?
  - ii. How might they have to adjust for the new medium of the water?
  - iii. Would they line up the pole with where they want the tag to go? Or would they aim lower or higher, and why that direction?"

Have students discuss their answers and then share out with the class.

Consider allowing students who need literacy support to work in pairs; later you can make a copy of the work completed for the other student to add to their Science Notebook. Alternatively, allow students to do this work in their native language.

12. Point out that this phenomenon of how light distorts our perception has real consequences for white sharks. Show students the video [San Clemente Sharks May 10, 2017](#). Let students know this is actual footage from a sheriff's helicopter surveying the coast of San Clemente in Southern California and noticing white sharks in the water. Ask students to record a few observations in their Science Notebook and be ready to share. When sharing, make sure that someone mentions the sheriff is saying, "it (the white shark) is 10 feet and swimming away from shore." (That audio is at the 2 minute mark in case it needs to be replayed.)

- a. Ask students a few questions, such as the following:
  - i. What is the position of the helicopter camera to the shark? (Students might need help in realizing the camera zooms in from a far away angle. The helicopter is never directly flying over a shark, perpendicular to the shark.)
  - ii. Knowing the helicopter camera is not perpendicular to the shark, do you think that the shark is 10 feet long?
  - iii. What evidence do you have? Relate this to your experience with the gummy fish. What happens visually when light enters our eye, coming from the fish, at an angle?
  - iv. What happens to the angle of light when it goes from a thicker or denser medium to a less thick or dense medium?
  - v. If the angle increases when moving from a thicker or denser medium to a less thick or dense medium, do you think that the white shark is actually longer or shorter than the 10 feet that the sheriff stated?
  - vi. Even though a sheriff would be a source we consider to be an authority, is it possible that the comment was incorrect?
- b. Allow students to discuss as a team and share out answers with the class. Again, consider allowing students who need literacy support to work in pairs; later you can make a copy of the work completed for the other student to add to their Science Notebook. Alternatively, allow students to do this work in their native language.

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Expected student responses include the following:

- › *When I tried to spear the gummy fish, the spear went farther away from the fish than it was actually located, so the fish must be smaller than I thought.*
- › *When I try to dive into a pool to retrieve something, I have to dive at a shallower angle to actually end up at my object.*
- › *When the light was coming out of the medium (glass, acrylic, or gelatin) it “bent” away from the medium and the object, making the angle larger, so it looked bigger than it actually was.*
- › *I tried to spear both ends of the gummy fish, and both ends were not where I thought that they would be. They were both closer to the middle of the fish.*
- › *I think the sheriff was reporting what they thought was true but didn’t think about how the light changes our perception.*
- › *This makes me wonder if all of the news reports we hear about shark sizes are wrong.*

13. Now that we know how light behaves as a result of interactions with different mediums, we can acknowledge that we see objects larger or smaller than they really are. Ask students for their ideas about how we could confidently determine how large a white shark in the water actually is. Students might indicate we could measure it, but only if the shark was right up against a boat, or if you were directly above the shark in a helicopter or with a drone (not at an angle, as in the video). Ask students to record this thinking in their Science Notebook.
14. Inform students that the CSULB Shark Lab, concerned over public claims that sharks at the coast are “10 feet long,” came up with a solution! Project **8.8.R1: Tweet from the CSULB Shark Lab** and let students know that this is a 6-foot “target” they deploy on the surface of the water to help with better size estimation. Ask students to record what they think the implications of using a target for size comparison might be for public perception (which will be addressed in the last lesson) and discuss. Ask students to connect this back to the anchoring phenomenon, “Numerous reports suggest an increase in white shark encounters in the United States in recent years and the public is worried.” Ask what part of the phenomenon this helps us address. (To support student sensemaking, if it is not obvious, hopefully this addresses public concerns about large sharks off the coast of Southern California. If the sharks aren’t 10 feet long, how big are they? Students are about to learn in the next lesson that this area is a well known nursery, and larger sharks like 10 footers are rare.) Discuss and encourage students to record ideas in their Science Notebook.
15. Ask teams to consider what they have learned about light and size perception and ask them to revisit **8.1.H3: My Shark Encounter Claim Chart** from Lessons 8.1–8.7 and to add any new information that could be used to support any of the claims and subsequent evidence and reasoning.

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### TEACHER NOTE

Students in 4th grade explore the idea that an object can be seen when light is reflected from it and travels to their eyes. (**4-PS4-2 Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.** *[Assessment Boundary: Assessment does not include knowledge of specific colors reflected and seen, the cellular mechanisms of vision, or how the retina works.]*) What is new for them to think about in this middle school context is the idea that the type of material that light passes through will change how it moves. Students should be familiar with the idea of density as variations in temperature and salinity can cause a difference in density from 6th grade (ESS2.C) and density is a property of matter from 7th grade (PS1.A). In this lesson, students can discuss density (higher density = molecules are more compact) as something that can influence the speed of light, and therefore, the “bending” of light at the transition of the two densities, but quantification of density is not required.

We perceive objects, like white sharks swimming in the water, as being larger because as light reflects back to your eye from the shark (going from water/more dense, to air/less dense), it bends away from the normal line. (For example, when the laser goes from the acrylic block/gelatin to the air, the angle that the light exits back into the air is greater than the angle that it enters it. Our eyes could perceive that as making the object appear larger.) So in the case of the white shark, in real life, a larger angle of exit makes a smaller shark appear larger.

Differentiation suggestion: Instead of showing students **8.8.R1: Tweet from the CSULB Shark Lab** and discussing the implications of using a target for size comparisons, this section could also be used to challenge students, especially those who are more motivated or engaged, to come up with their own way to determine an accurate length of a white shark before introducing them to the solution that others came up with. Once students have determined a solution, they could compare the two to determine which idea would provide the most accurate estimation of length and what the limitation of each solution might be to helping the public be aware of the size of sharks in the water.

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### Accommodations

By seating students in groups (groups of 4 work well) and encouraging regular conversation, students have time to interact more with content and naturally help those that need more support. Use of **8.1.H2: Scientist Communication Survival Kit** (from Lesson 8.1: Shark Encounters) helps with making sure that students who don't feel comfortable sharing (often because of language, literacy level, uncertainty of content knowledge, etc.) are prompted to do so in a supportive way.

Use of a sense-making Science Notebook supports student language development, conceptual development, and metacognition. Students should be prompted to use their Science Notebook for

- prior knowledge of phenomena,
- exploration of phenomena and data collection,
- making sense of phenomena, and
- metacognition.

By writing about topics in their Science Notebook BEFORE discussing, second language learners and low language students can gain confidence and organize their thoughts before speaking in front of a group. Also, sharing ideas in a small group throughout the rest of the lesson lowers the affective filter of low language students. Having students work in teacher-selected partnerships or groups allows you to match students in a way that both are being supported. Advanced students have the opportunity to explore additional questions that arise.

Consider providing sentence frames for low literacy and second language learners. The use of graphic organizers can help struggling students manage Science Notebook work.

When showing a short video, it's often helpful to students to watch the video once to get a sense of the purpose. Showing the video a second (and sometimes a third time) allows students to focus on important details that can be recorded in their Science Notebook and discussed.

### References

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## Refraction Investigation

### Instructions:

1. Place the medium (glass, acrylic, or gelatin) in the middle of a piece of white paper.
2. Trace the outline of the medium and then remove it from the paper.
3. Draw a line perpendicular (normal line) to the new medium along one of the longer sides a little off from center.
4. Measure a  $30^\circ$  angle from the normal line and draw a line with a colored pencil.
5. Place the medium back on the paper in the same spot (on top of the tracing) and shine the laser along the  $30^\circ$  line that you drew. Trace the laser light that comes out the other side.
6. Connect the inside ray to the outside rays.
7. Make a new normal line on the other side of the medium that is perpendicular to the surface.
8. Measure all of the angles that the rays make with the normal lines.
9. Using different colored pencils, repeat this process for  $45^\circ$  and  $60^\circ$ .

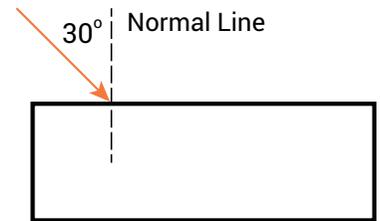


Image by WestEd [CC BY-NC-SA 4.0]

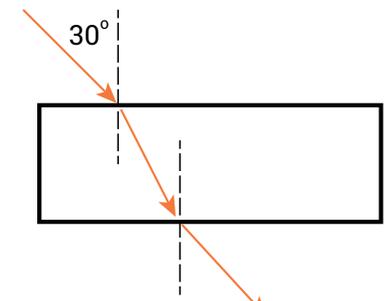


Image by WestEd [CC BY-NC-SA 4.0]

Initial Angle	Angle 1	Angle 2	Angle 3
$30^\circ$			
$45^\circ$			
$60^\circ$			

### Questions:

1. What patterns do you find between the angles for a given situation (i.e., for only the  $30^\circ$  initial angle situation)?
2. What patterns do you find as you increase the first angle?
3. What do you attribute to these patterns?
4. Make a prediction for the angles you think would take place if the first angle were  $10^\circ$ . What evidence helps you make this prediction?
5. Make a prediction for how you think your angles would change if we replaced the medium with one that was denser than the one you used.

## Tweet from the CSULB Shark Lab

A 6-foot “shark target” that is deployed on the surface of the water and used for white shark size estimation.



Source: Lowe, C. [CSULBsharklab]. (2017, June 3). [Tweet]. Retrieved from <https://twitter.com/CSULBsharklab/status/871070923213819906>  
[Reproduced with permission]

# Appendix 8.8

## Light, Which Way Does It Go?

### Next Generation Science Standards (NGSS)

This lesson is building toward:

#### PERFORMANCE EXPECTATIONS (PE)

<b>MS-PS4-2</b>	Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]
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NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

#### SCIENCE AND ENGINEERING PRACTICES (SEP)

##### Developing and Using Models

- Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed.
- Develop and/or use a model to predict and/or describe phenomena.

##### Analyzing and Interpreting Data

- Analyze and interpret data to provide evidence for phenomena.

#### DISCIPLINARY CORE IDEAS (DCI)

##### PS4.B: Electromagnetic Radiation

- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.

#### CROSSCUTTING CONCEPTS (CCC)

##### Patterns

- Patterns can be used to identify cause and effect relationships.

##### Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

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## Appendix 8.8

### Common Core State Standards (CCSS)

#### CCSS ELA SCIENCE & TECHNICAL SUBJECTS

##### CCSS.ELA-LITERACY.RST.6-8.3

Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

#### CCSS ELA WRITING

##### CCSS.ELA-LITERACY.WHST.6-8.2.F

Provide a concluding statement or section that follows from and supports the information or explanation presented.

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### California English Language Development (ELD) Standards

#### CA ELD

**Part 1.8.12:** Selecting and applying varied and precise vocabulary and other language resources to effectively convey ideas

#### EMERGING

##### P1.8.12

- Use a select number of general academic words (e.g., *specific, contrast*) and domain-specific words (e.g., *scene, cell, fraction*) to create some precision while speaking and writing.
- Use knowledge of morphology to appropriately select affixes in basic ways (e.g., *She likes X. He walked to school.*).

#### EXPANDING

##### P1.8.12

- Use a growing set of academic words (e.g., *specific, contrast, significant, function*), domain-specific words (e.g., *scene, irony, suspense, analogy, cell membrane, fraction*), synonyms, and antonyms to create precision and shades of meaning while speaking and writing.
- Use knowledge of morphology to appropriately select affixes in a growing number of ways to manipulate language (e.g., *She likes walking to school. That's impossible.*

#### BRIDGING

##### P1.8.12

- Use an expanded set of general academic words (e.g., *specific, contrast, significant, function, adequate, analysis*), domain-specific words (e.g., *scene, irony, suspense, analogy, cell membrane, fraction*), synonyms, antonyms, and figurative language to create precision and shades of meaning while speaking and writing.
- Use knowledge of morphology to appropriately select affixes in a variety of ways to manipulate language (e.g., *changing destroy -> destruction, probably -> probability, reluctant -> reluctantly*).

In addition to the standard above, you may find that you touch on the following standards in this lesson as well:

- P1.8.1:** Exchanging information and ideas with others through oral collaborative discussions on a range of social and academic topics
- P1.8.2:** Interacting with others in written English in various communicative forms (print, communicative technology and multimedia)
- P1.8.3:** Offering and justifying opinions, negotiating with and persuading others in communicative exchanges
- P1.8.5:** Listening actively to spoken English in a range of social and academic contexts
- P1.8.10:** Writing literary and informational texts to present, describe, and explain ideas and information, using appropriate technology
- P2.8.5:** Modifying to add details
- P2.8.6:** Connecting ideas
- P2.8.7:** Condensing ideas

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