Exploring the Science of Reflectivity: Curriculum for Grades 4 through 6

October 2018 | Final Report

SAFE-D
SAFETY THROUGH DISRUPTION

VT TRANSPORTATION INSTITUTE
VIRGINIA TECH.

Texas A&M Transportation Institute

San Diego State University
Leadership Starts Here

Disclaimer

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. TTI-01-05	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Exploring the Science of Retroreflectivity: Curriculum for Grades 4 through 6		5. Report Date Published: October 2018 6. Performing Organization Code:
7. Author(s) Melisa D. Finley Stephanie Hanover Susan T. Chrysler		8. Performing Organization Report No. Report TTI-01-05
9. Performing Organization Name and Address: Safe-D National UTC Texas A&M Transportation Institute The Texas A&M University System College Station, Texas 77843-3135		10. Work Unit No. 11. Contract or Grant No. 69A3551747115/Project TTI-01-05
12. Sponsoring Agency Name and Address Office of the Secretary of Transportation (OST) U.S. Department of Transportation (US DOT) State of Texas		13. Type of Report and Period Final Research Report 14. Sponsoring Agency Code

15. Supplementary Notes

This project was funded by the Safety through Disruption (Safe-D) National University Transportation Center, a grant from the U.S. Department of Transportation – Office of the Assistant Secretary for Research and Technology, University Transportation Centers Program, and, in part, with general revenue funds from the State of Texas.

16. Abstract

According to the United States Department of Commerce, careers in science, technology, engineering, and mathematics (STEM) are growing faster than occupations in other areas. However, in-class academic concepts can seem abstract with little relevance to a student's life. There is therefore a need for in-class curricula that links academic concepts with real-world STEM applications.

Over the past 10 years, Texas A&M Transportation Institute (TTI) researchers have developed many educational activities for elementary and middle school students (K–8) that provide an opportunity to gain hands-on experience and insight into what transportation engineering and other STEM careers have to offer. In 2011, a TTI researcher taught approximately 300 fifth graders about the scientific principles of reflection, refraction, and retroreflectivity through a brief history of sign sheeting, hands-on activities, and a laboratory exercise. While these activities successfully engaged the students, it is not possible for one researcher to visit the numerous K–12 classrooms in their area, much less on a state- or nation-wide level. Therefore, TTI researchers created a curriculum and associated materials that can be used by teachers and other professionals to connect real-world applications in transportation to academic concepts to enhance the STEM learning experience for students.

17. Key Words STEM, Transportation, Retroreflectivity, Reflection, Refraction, Curriculum		18. Distribution Statement No restrictions. This document is available to the public through the Safe-D National UTC website, as well as the following repositories: VTechWorks, The National Transportation Library, The Transportation Library, Volpe National Transportation Systems Center, Federal Highway Administration Research Library, and the National Technical Reports Library.	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 129	22. Price $0

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Abstract

According to the United States Department of Commerce, careers in science, technology, engineering, and mathematics (STEM) are growing faster than occupations in other areas. However, in-class academic concepts can seem abstract with little relevance to a student's life. There is therefore a need for in-class curricula that links academic concepts with real-world STEM applications.

Over the past 10 years, Texas A&M Transportation Institute (TTI) researchers have developed many educational activities for elementary and middle school students (K–8) that provide an opportunity to gain hands-on experience and insight into what transportation engineering and other STEM careers have to offer. In 2011, a TTI researcher taught approximately 300 fifth graders about the scientific principles of reflection, refraction, and retroreflectivity through a brief history of sign sheeting, hands-on activities, and a laboratory exercise. While these activities successfully engaged the students, it is not possible for one researcher to visit the numerous K–12 classrooms in their area, much less on a state- or nation-wide level. Therefore, TTI researchers created a curriculum and associated materials that can be used by teachers and other professionals to connect real-world applications in transportation to academic concepts to enhance the STEM learning experience for students.

Acknowledgements

This project was funded by the Safety through Disruption (Safe-D) National University Transportation Center, a grant from the U.S. Department of Transportation – Office of the Assistant Secretary for Research and Technology, University Transportation Centers Program, and, in part, with general revenue funds from the State of Texas.

The authors gratefully acknowledge the contributions of Jayson Stibbe (TTI Graduate Research Assistant) and Allen Academy in Bryan, Texas. Jayson assisted with the development of the curriculum and Allen Academy graciously provided teachers and classrooms for TTI to evaluate the curriculum.

The authors also express gratitude to Dr. Paul Carlson (Subject Matter Expert) who reviewed this report.

Table of Contents

List of Figures

List of Tables

Introduction

According to the United States Department of Commerce, careers in science, technology, engineering, and mathematics (STEM) are growing faster than occupations in other areas. The transportation industry relies heavily on the STEM fields to solve mobility and safety issues for all users. However, math and science scores on average among U.S. students are lagging behind those of students in other developed countries. In addition, research has found that most Americans thought their traditional STEM related classes were boring and had no relevance to their life (*1*). Methods to change this perspective include engaging students with real-life applications, working in teams to solve real-life problems, and/or participating in tours. Unfortunately, most of these activities occur outside of the classroom. All of this points to a need for in-class curriculum that links academic concepts with real-world STEM applications.

Over the past 10 years, Texas A&M Transportation Institute (TTI) researchers have developed many educational activities for elementary and middle school students (K–8) that provide an opportunity to gain hands-on experience and insight into what transportation engineering and other STEM careers have to offer. While researchers developed most of these activities for use during student visits to TTI, some of the material has been presented to students in a classroom setting. For example, in 2011, a TTI researcher taught approximately 300 fifth graders about the scientific principles of reflection, refraction, and retroreflectivity through a brief history of sign sheeting, hands-on activities, and a laboratory exercise. While these activities successfully engaged the students, it is not possible for one researcher to visit the numerous K–12 classrooms in their area, much less on a state- or nation-wide level. Therefore, TTI researchers created curriculum and associated materials that can be used by teachers and other professionals to connect real-world applications in transportation to these academic concepts to enhance the STEM learning experience for students.

Overview of Curriculum

The following sections provide an overview of the Exploring the Science of Retroreflectivity curriculum. The actual curriculum and associated materials are located in the Appendices.

Connecting the Classroom to the Roads

Kids see signs everywhere on the road. Some signs advertise businesses, some convey a message about a product or service, and others help guide travelers to their destinations safely. The latter are categorized as road signs, and while they may look like ordinary signs, there is some amazing engineering that goes into every one of them. Most drivers and passengers are completely unaware of the science behind the signs. This curriculum seeks to help students use discovery techniques and STEM lessons to better understand the characteristics of light as they navigate through the activities and challenges that follow the history of road signs.

Learning Objectives

The curriculum was developed to complement traditional teaching methods and meet Next General Science Standards (NGSS) and Texas Essential Knowledge Standards (TEKS) for grades 4 through 6. Specific NGSS and state standards are incorporated into each lesson, with extensions and modified lessons included for time allowances and informal education opportunities. After completing the curriculum, students will:

- understand the visible light portion of the electromagnetic spectrum.
- understand reflection, refraction, absorption, transmission, diffusion, and retroreflection of light.
- have the ability to collect and analyze relevant data and draw logical conclusions.
- have the ability to design and construct models to test ideas using criteria for functionality, effectiveness, and constraints in materials.
- understand how new technologies help improve current ideas for increased benefits.
- understand a basic engineering design process including: define, plan, make, test, and reflect.
- understand how engineering for retroreflection connects to careers and real-world problem solving.

Lessons

The five lessons described below were built out to the 5E model (engage, explore, explain, elaborate, and evaluate) with at least one student activity or lesson per section. Each lesson builds from the prior lesson and can be utilized in its entirety or broken apart to meet learning and time constraints. Each lesson provides background information, activity plans, a supply list, vocabulary, and teacher preparation information.

Engage – What Do We See?

In this lesson, students investigate what we see and why. Why is the table black? Why is the chair shiny? Why is the rug blue? What if it is clear? What color is sunlight? What is emission? What is transmission? What is reflection? What is absorption? How do reflection and absorption determine the colors we see?

Explore – How Does Light Travel?

In this lesson, students analyze more properties of reflection, including angle of reflection, amount of both reflection and absorption, and also diffusion and refraction through various medians. Some colors are brighter, some are darker. This lesson will allow students to use their observational skills to answer these and other questions based on reflection, absorption, transmission, and refraction of light. If a laser is pointed at the mirror, what direction will it go? What colors are better at absorbing light? What causes diffusion of light? Can we bend light?

Explain – Can We Change What We See?

In this activity, students investigate how glass spheres can change what we see and how they can help drivers see traffic signs clearly in the dark. What makes a sign more visible at night? What colors offer better reflection at night? What is retroreflection? How do we bend and bounce light back to the source from several different angles, using refraction and reflection to our advantage?

Elaborate – Can We Control What We See?

In this activity, students will learn and use the engineering design process. They will design, construct, and test retroreflection of a traffic sign to maximize its visibility to a driver at night.

Evaluate – Can We Make Good Better?

Students will be introduced to new technologies in retroreflection. Even when things work, engineers and scientists are always trying to find better solutions. At TTI, researchers strive to develop new ways to make the roads safer for everyone, every day. In this lesson, students will compare various retroreflective materials to determine which technologies are the most effective, allowing drivers to see them in time to make safe driving decisions.

Lesson details can be found in Appendix A. Some activities have associated lab worksheets. These lab worksheets and the answer key can be found in Appendix B. A presentation slide deck is also available (see Appendix C). Slides are provided to aid teachers with demonstrations, student activities, and class discussion questions. The slide deck also contains fun facts in transportation. The slides can be used in their entirety or as needed.

Table 1 contains the recommended teaching time for each lesson. The first three units (Engage, Explore and Explain) are background lessons leading to the retroreflectivity units (Elaborate and Evaluate). Teachers may choose to do all, some, or none of the background units depending upon students' prior knowledge.

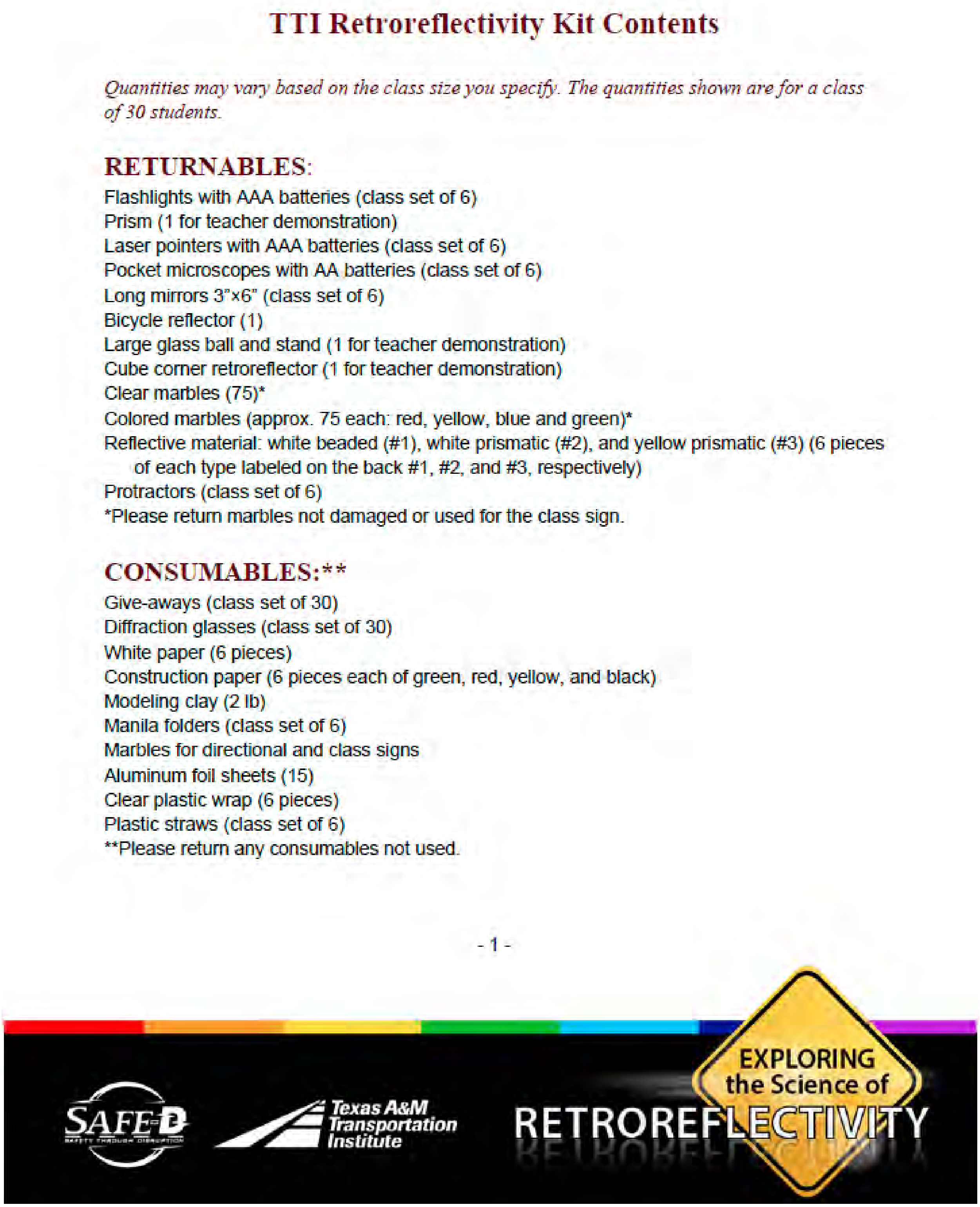
Material Kit

While a list of materials is available for each lesson so that educators can procure their own supplies if desired, TTI has eight pre-assembled kits that are ready to go for a classroom. Each kit contains most of the supplies needed to complete the lessons in their entirety (student activities and teacher demonstrations), including items that may not be readily available in the classroom. Each kit contains both returnable and consumable items for a classroom of 30 students and can be customized to meet the needs of several classes (see Figure 1). Items not in the kit include: crayons or map pencils, scissors, glue, clear tape, extra paper, and 300 ml beakers or clear drinking glasses.

Table 1. Recommended Teaching Time

ACTIVITY	DESCRIPTION	TIME
ENGAGE UNIT	**WHAT DO WE SEE?**	**45–50-minute class**
ENGAGE-TD-1	A Rainbow of Light	10–15 minutes
ENGAGE-SA-1	Rainbow Glasses	10–15 minutes
ENGAGE-SA-2	Comparison of Colors, Reflection, and Absorption	20 minutes
EXPLORE UNIT	**HOW DOES LIGHT TRAVEL?**	**45–50-minute class**
EXPLORE-SA-1	Angle of Reflection	10 minutes
EXPLORE-SA-2	Diffusion	15 minutes
EXPLORE-SA-3	Refraction	20 minutes
EXPLAIN UNIT	**CAN WE CHANGE WHAT WE SEE?**	**30-minute class**
EXPLAIN-TD-1	Light through a Glass Sphere	15 minutes
EXPLAIN-SA-1	Does Color Matter?	15 minutes
EXTENSION-1	*Measuring Headlights and Calculating Averages*	*30–45 minutes*
ELABORATE UNIT	**CAN WE CONTROL WHAT WE SEE?**	**Two 45-minute classes**
ELABORATE-SA-1	Engineering Design Process Challenge	1 hour 30 minutes
EXTENSION-2	*Building Better Models*	*20–45 minutes*
EVALUATE UNIT	**CAN WE MAKE GOOD BETTER?**	**Three 45-minute classes**
EVALUATE-TD-1	Prismatic Retroreflection	10 minutes
EVALUATE-SA-1	A Closer Look	20 minutes
EVALUATE-SA-2	Test Engineering	60 minutes
EVALUTE-SA-3	Sharing Solutions	45 minutes
EXTENSION-3	*Creating a Class Retroreflective Sign*	*30 minutes*

UNIT TIME: time required to complete the entire lesson with information, student activities, teacher demonstrations, and lab sheets. This time does not include extensions.
STUDENT ACTIVITY (SA): time required to complete each individual activity and associated lab sheet.
TEACHER DEMONSTRATION (TD): time required to complete the teacher demonstration and associated lab sheet.
EXTENSION: the estimated time required to complete only the extension activity, separate from the unit time.



TTI Retroreflectivity Kit Contents

Quantities may vary based on the class size you specify. The quantities shown are for a class of 30 students.

RETURNABLES:

Flashlights with AAA batteries (class set of 6)
Prism (1 for teacher demonstration)
Laser pointers with AAA batteries (class set of 6)
Pocket microscopes with AA batteries (class set of 6)
Long mirrors 3"×6" (class set of 6)
Bicycle reflector (1)
Large glass ball and stand (1 for teacher demonstration)
Cube corner retroreflector (1 for teacher demonstration)
Clear marbles (75)*
Colored marbles (approx. 75 each: red, yellow, blue and green)*
Reflective material: white beaded (#1), white prismatic (#2), and yellow prismatic (#3) (6 pieces of each type labeled on the back #1, #2, and #3, respectively)
Protractors (class set of 6)
*Please return marbles not damaged or used for the class sign.

CONSUMABLES:**

Give-aways (class set of 30)
Diffraction glasses (class set of 30)
White paper (6 pieces)
Construction paper (6 pieces each of green, red, yellow, and black)
Modeling clay (2 lb)
Manila folders (class set of 6)
Marbles for directional and class signs
Aluminum foil sheets (15)
Clear plastic wrap (6 pieces)
Plastic straws (class set of 6)
**Please return any consumables not used.

- 1 -

Figure 1. Material kit contents.

Curriculum Evaluation

In the fall of 2017, two teachers at Allen Academy in Bryan, Texas taught the Exploring the Science of Retroreflectivity curriculum to fifth and sixth grade students. Researchers revised the curriculum and associated materials based on the feedback received from the teachers and in-class observations.

Promotional Activities

On March 30, 2017, two TTI researchers exhibited at the 2017 STEM 4 Innovation Conference for K–12 Education in College Station, Texas. These researchers promoted the Exploring the Science of Retroreflectivity curriculum, which was under development, and student visits to the TTI facilities.

On January 25, 2019, three TTI researchers exhibited at the 2018 STEM 4 Innovation Conference for K–12 Education in College Station, Texas (see Figure 2). These researchers promoted the Exploring the Science of Retroreflectivity curriculum by handing out brochures about the curriculum, talking with teachers, and demonstrating some of the student activities and in-class curriculum evaluations.

Figure 2. 2018 STEM 4 Innovation Conference exhibit.

Additional Products

The Exploring the Science of Retroreflectivity curriculum and associated materials are located at https://tti.tamu.edu/safe-d. Teachers and other professionals interested in using the curriculum may contact STEM@tti.tamu.edu for a materials kit or more information.

Education and Workforce Development Products

This educational development project focused on the enhancement and expansion of in-class STEM activities that connect real-life applications to academic concepts. The target users are teachers and other transportation professionals. The student audience is students in grades 4–6.

Technology Transfer Products

The technology transfer products included:

- development of promotional materials (brochure and video).
- publication of the curriculum and associated materials online.
- promotion of the curriculum at conferences.
- development of four “train the trainer” videos (available online).
- creation of material kits that can be supplied to teachers upon request.

References

1. Kennedy, B., M. Hefferon, and C. Funk. *Half of Americans think young people don’t pursue STEM because it is too hard*. Online article published by Pew Research Center. January 17, 2018. Available at http://www.pewresearch.org/fact-tank/2018/01/17/half-of-americans-think-young-people-dont-pursue-stem-because-it-is-too-hard/. Accessed October 2, 2018.

Appendices

Appendix A – Teacher Lesson Plans

Appendix A contains the teacher lesson plans. The five lessons were built out to the 5E model (engage, explore, explain, elaborate, and evaluate) with at least one student activity or lesson per section. Each lesson builds from the one prior and can be utilized in its entirety or broken apart to meet learning and time constraints. Each lesson provides background information, activity plans, a supply list, vocabulary, and teacher preparation information.

Exploring the Science of Retroreflectivity

Texas A&M Transportation Institute
Melisa Finley
Sue Chrysler
Stephanie Hanover
Jayson Stibbe

Overall Objective

Our goal is to connect real-life applications in transportation to academic concepts to enhance the STEM (science, technology, engineering, and math) learning experience for students.

Connecting the Classroom to the Roads

Kids see signs everywhere. Some signs show businesses, some tell us about a product or service and others help us find our destination. The latter are road signs, and while they may look like ordinary signs, there is some amazing engineering that goes into every one of them. Most drivers and passengers never notice the science behind the signs. This unit seeks to help students use discovery techniques and STEM lessons to better understand the characteristics of light as they navigate through the activities and challenges that follow the history of road safety and innovations. Come along for the ride that guarantees to have your students looking out the windows with a new perspective as they travel!

STEM with Emphasis on the E

These lessons were specifically developed with engineering in mind. This unit is molded to fit the standards of engineering design of NGSS for grades 4–6. Specific NGSS and state standards are incorporated into each division, with extensions and modified lessons included for time allowances and informal education opportunities. Each lesson provides background information, activity plans, a supply list, a timetable, and teacher preparation information. The unit is built out to the 5E model (engage, explore, explain, elaborate, and evaluate) with at least one student activity or lesson per section. Each lesson builds from the one prior and can be utilized in its entirety or broken apart to meet learning and time constraints.

TTI Retroreflectivity Kit for Teachers

While a list of materials is available for each lesson, the Texas A&M Transportation Institute (TTI) has a kit ready to go for your classroom! The kit contains most of the supplies needed to complete these activities in their entirety, including items that may not be readily available in the classroom, and has materials for student activities and teacher demonstrations. Each kit contains returnable and consumable items for a classroom of 30 students and can be customized to meet the needs of several classes. Contact STEM@tti.tamu.edu to arrange pickup or delivery of the TTI Retroreflectivity Kit for your classroom.

RETROREFLECTION!

RETROREFLECTION FOR GRADES 4–6

LEARNING OBJECTIVE

There is more to transportation safety than meets the eye! There is science behind everything we see. Retroreflection builds upon the more common characteristics of light, including reflection, refraction, absorption, diffusion, and transmission to control light in a way that makes signs and roadway markers more visible to drivers and our streets and highways safer for everyone. Students will understand these concepts through STEM-related activities that guide them in discovering these truths for themselves. They will collect, analyze, and draw conclusions with real and relevant data. They will apply new and prior knowledge to design models to test retroreflection with various materials.

After completing this unit of activities, students will:

- understand the visible light portion of the electromagnetic spectrum.

- understand reflection, refraction, absorption, transmission, diffusion, and retroreflection of light.

- have the ability to collect and analyze relevant data and draw logical conclusions.

- have the ability to design and construct models to test ideas using criteria for functionality, effectiveness, and constraints in materials.

- understand how new technologies help us improve current ideas for increased benefits.

- understand a basic engineering design process including: define, plan, make, test, and reflect.

- understand how engineering for retroreflection connects to careers and real-world problem solving.

FEEDBACK

We would like to hear from you! Please share your thoughts on how you used the lessons and photos of your students completing activities along with completed projects. We also welcome your experience in ways we can work to make the unit even better for teachers, students, and facilitators. Please send information and photos to STEM@tti.tamu.edu.

Student Activities Grades 4–6

ENGAGE – WHAT DO WE SEE?

Students will investigate what we see and why.

Why is the table black? Why is the chair shiny? Why is the rug blue? What if it is clear? What color is sunlight? What is emission? What is transmission? What is reflection? What is absorption? How do reflection and absorption determine the colors I see?

EXPLORE – HOW DOES LIGHT TRAVEL?

In this lesson, students will analyze more properties of reflection, including angle of reflection, amount of both reflection and absorption, and also diffusion and refraction through various medians. Some colors are brighter, some are darker. This lesson will allow them to use their observational skills to answer these and other questions based on reflection, absorption, transmission, and refraction of light.

If a laser is pointed at the mirror, what direction will it go? What colors are better at absorbing light? What causes diffusion of light? Can we bend light?

EXPLAIN – CAN WE CHANGE WHAT WE SEE?

In this activity, students will investigate how glass spheres can change what we see and how they can help drivers see traffic signs clearly in the dark.

What makes a sign more visible at night? What colors offer better reflection at night? What is retroreflection? How do we bend and bounce light back to the source from several different angles, using refraction and reflection to our advantage?

ELABORATE – CAN WE CONTROL WHAT WE SEE?

In this activity, students will learn and use the engineering design process. They will design, construct, and test retroreflection on a traffic sign to maximize visibility at night to a driver.

What does it mean to be effective? What are constraints? What are criteria for success?

EVALUATE – CAN WE MAKE GOOD BETTER?

Students will be introduced to new technologies in retroreflection. Even when things work, we are always trying to find better solutions. At Texas A&M Transportation Institution, we strive to develop new ways to make the roads safer for everyone, every day. In this unit, students will compare various retroreflective materials to determine which technologies are the most effective, allowing drivers to see them in time to make safe driving decisions.

How can I collect data that are meaningful to my investigation? What factors should I consider when comparing the effectiveness of a product? Does my investigation provide the same opportunities for success and failure for all the items tested?

RECOMMENDED TEACHING TIME

The first three units (Engage, Explore and Explain) are background lessons leading to the retroreflectivity units (Elaborate and Evaluate). Teachers may choose to do all, some or none of the background units dependent upon the prior knowledge of the students.

ACTIVITY	DESCRIPTION	TIME
ENGAGE UNIT	**WHAT DO WE SEE?**	**45–50-minute class**
ENGAGE-TD-1	A Rainbow of Light	10–15 minutes
ENGAGE-SA-1	Rainbow Glasses	10–15 minutes
ENGAGE-SA-2	Comparison of Colors, Reflection, and Absorption	20 minutes
EXPLORE UNIT	**HOW DOES LIGHT TRAVEL?**	**45–50-minute class**
EXPLORE-SA-1	Angle of Reflection	10 minutes
EXPLORE-SA-2	Diffusion	15 minutes
EXPLORE-SA-3	Refraction	20 minutes
EXPLAIN UNIT	**CAN WE CHANGE WHAT WE SEE?**	**30-minute class**
EXPLAIN-TD-1	Light through a Glass Sphere	15 minutes
EXPLAIN-SA-1	Does Color Matter?	15 minutes
EXTENSION-1	*Measuring Headlights and Calculating Averages*	*30–45 minutes*
	Retroreflection begins here:	
ELABORATE UNIT	**CAN WE CONTROL WHAT WE SEE?**	**Two 45-minute classes**
ELABORATE-SA-1	Engineering Design Process Challenge	1 hour 30 minutes
EXTENSION-2	*Building Better Models*	*20–45 minutes*
EVALUATE UNIT	**CAN WE MAKE GOOD BETTER?**	**Three 45-minute classes**
EVALUATE-TD-1	Prismatic Retroreflection	10 minutes
EVALUATE-SA-1	A Closer Look	20 minutes
EVALUATE-SA-2	Test Engineering	60 minutes
EVALUTE-SA-3	Sharing Solutions	45 minutes
EXTENSION-3	*Creating a Class Retroreflective Sign*	*30 minutes*

UNIT TIME: time required to complete the entire lesson with information, student activities, teacher demonstrations, and lab sheets. This time does not include extensions.

STUDENT ACTIVITY (SA): time required to complete each individual activity and associated lab sheet.

TEACHER DEMONSTRATION (TD): time required to complete the teacher demonstration and associated lab sheet.

EXTENSION: the estimated time required to complete only the extension activity, separate from the unit time.

TTI RETROREFLECTIVITY KIT

RETURNABLES:

Flashlights with AAA batteries (class set of 6)
Prism (1 for teacher demonstration)
Laser pointers with AAA batteries (class set of 6)
Pocket microscopes with AA batteries (class set of 6)
Long mirrors 3”×6” (class set of 6)
Bicycle reflector (1)
Large glass ball and stand (1 for teacher demonstration)
Cube corner retroreflector (1 for teacher demonstration)
Clear marbles (75)*
Colored marbles (approx. 75 each: red, yellow, blue and green)*
Reflective material: white beaded (#1), white prismatic (#2), and yellow prismatic (#3) (6 pieces of each type labeled on the back #1, #2, and #3, respectively)
Protractors (class set of 6)
*Please return marbles not damaged or used for the class sign.

CONSUMABLES:**

Give-aways (class set of 30)
Diffraction glasses (class set of 30)
White paper (6 pieces)
Construction paper (need 6 pieces each of green, red, yellow, and black)
Modeling clay (2 lb)
Manila folders (class set of 6)
Marbles for directional and class signs
Aluminum foil sheets (15)
Clear plastic wrap (6 pieces)
Plastic straws (class set of 6)
**Please return any consumables not used.

NOT INCLUDED IN KIT:

Crayons or map pencils
Scissors
Glue
Clear tape
Extra paper

300ml beaker or clear drinking glasses (class set of 6)
Materials to make your own Playdoh, if desired
Student lab sheets are available to download and print, as needed.

The amount of materials included in each kit may vary based on class size. The amounts shown are for a class of 30 students.

EXPLORING the Science of RETROREFLECTIVITY

FORMAT FOR EACH UNIT

UNIT TITLE

Each unit will begin with the general topic of what you can expect students to learn.

There is a host of questions that students will be able to answer upon completion of the unit.

MATERIALS FOR STUDENTS

Per student: materials

Per group: the kit is designed for a class of 30, 6 groups of 5 students each. Assign groups that work for your students; this is written for 6 groups per class.

MATERIALS FOR TEACHER

These are materials you will need for teacher demonstrations or to provide students additionally as needed or requested.

VOCABULARY

The vocabulary is provided to the teacher and can be presented to students in any manner (e.g., before the lesson, as the lesson progresses).

TEACHER BACKGROUND

This section is intended to help the teachers navigate each teacher demonstration, student activity, and class discussion questions.

Slides are provided to aid teachers in each teacher demonstration, student activity, class discussion questions, and fun facts in transportation. They can be used with the class in their entirety or as needed. All units can be completed without the use of the slides except for fun facts in transportation.

TEACHER DEMONSTRATION: Unit-Number: LESSON TITLE

Each teacher demonstration will include instructions, background information, and provide questions for the students, most found directly on the student lab sheets.

Class Discussion Questions: These questions serve as quick checks for the teacher that students are understanding the concepts presented in the teacher demonstrations and/or student activities. General answers are provided for teachers.

STUDENT ACTIVITY: Unit-Number: LESSON TITLE

Student activities will describe the activity and objective of lesson. It will also provide teacher insight and special instructions.

COOL FACT: Interesting facts that are associated with lesson.

VIDEOS – TOPIC: Title and Link (Video links are also provided in the slides.)

EXTENSION 1: TITLE

LESSON TOPIC. Extension activities provide additional activities for some units and are unique in their purpose. They serve to provide more real-world simulation, data collection, and math application as well as individual creativity.

FUN FACTS IN TRANSPORTATION (on slides):
These fun facts serve to connect the lessons to the real world of transportation. They can also be used as warm-up activities to preview or review data or as mastery checks to analyze understanding following activities.

STUDENT LAB SHEET
A student lab sheet is provided for each unit. The lab sheet may be used in entirety, act as a guide, used only in portions, all at the discretion of the teacher.

ENGAGE – WHAT DO WE SEE?

Students will investigate why and what we see.

Why is the table black? Why is the chair shiny? Why is the rug blue? What if it is clear? What color is sunlight? What is emission? What is transmission? What is reflection? What is absorption?

This lesson is designed to introduce students to the visible section of the electromagnetic spectrum and understand that visible light is made up of many colors. Understanding this, students can begin to see how colors are reflected in everything around them.

The lab sheet begins with background information and vocabulary on emission, transmission, and absorption of light. This information should be completed by the students prior to the teacher demonstration.

MATERIALS FOR STUDENTS

Per student: Engage Unit lab sheet; diffraction glasses

Per group: flashlight; various colors of construction paper (white, green, red, yellow, and black); clear plastic wrap; red, orange, yellow, green, blue, indigo and violet crayons* or map pencils*

*Items not included in TTI kit. For this activity, students can write as an alternative to coloring.

MATERIALS FOR TEACHER

Sunlight or white light projector*; prism

*Items not included in TTI kit.

VOCABULARY

White Light: the combination of many different wavelengths of light from the different parts of the visible light spectrum.

Emission: the production and sending out of light or energy.

Transmission: light moving through a medium such as air, water, or glass.

Medium: a substance through which energy or light travels (e.g., space, air, or water).

Absorption: light is not reflected, but instead, taken in and converted to heat.

Reflection: light waves bouncing off of a surface.

EXPLORING the Science of RETROREFLECTIVITY

TEACHER BACKGROUND

TEACHER DEMONSTRATION Engage-1: A Rainbow of Light

Hold the prism up to the sunlight or other source of white light in the classroom. Explain that the sun emits light, which is transmitted through various mediums. The sun produces and sends white light through the prism, which separates white light into the component colors of red, orange, yellow, green, blue, indigo, and violet (ROY G BIV). You will need to make sure the light falls onto a white surface for students to view the colors with optimal differentiation. Students will color in the colors and/or write the color for each ray of light on the lab sheet. Explain that we see the colors of a rainbow individually or in combination such as teal, lavender, pink, brown, etc.

STUDENT ACTIVITY Engage-1: Rainbow Glasses

Students will look through diffraction glasses at other sources of white light, such as the overhead lights in the classroom, lamps, etc., and describe what colors and patterns they see. LED light bulbs will produce all the colors (ROY G BIV). This will give each student a more individual approach to the investigation and allow them a unique way to explore the colors of ROY G BIV. There are reflection questions on the lab sheet for this activity. If there is a window in the classroom, remind students to NEVER LOOK AT THE SUN!

STUDENT ACTIVITY Engage-2: Comparison of Colors, Reflection, and Absorption

Students will shine flashlights at various colors of construction paper to determine color and will rank the various colors according to the amount of visible absorption and reflection on the lab sheet. Any color construction paper may be used; white, black, green, yellow, and red construction paper are provided in the kit as they represent common traffic sign colors (choose four colors). The classroom will need to be as dark as possible for students to perform the investigation. Explain the differences between reflection and absorption or have the students define them prior to this activity. Black should absorb the most and reflect the least. White should be the opposite: absorbing the least and reflecting the most. Students have an explanation on their sheet about why each object is the color that it is. Objects appear white when the light reflects; conversely, we see all the colors as the white light bounced back. In black, all the colors are absorbed, and we see no color. For red, green, and yellow, all colors are absorbed except for the red, green, and yellow, respectively, that reflect or bounce back to our eyes, causing us to see red, green, and yellow. The darker colors should have higher absorption while the lighter colors should have higher reflection.

> **Class Discussion Question:** Hold up or point to various objects around the room (or use the slide provided). What color, or colors, are reflected for each object? What color, or colors, are absorbed? How do you know?

FUN FACTS IN TRANSPORTATION

The fun facts in transportation are located in the slide presentation.

STUDENT LAB SHEET – ENGAGE

A student lab sheet is available in the 5E format for use at the teacher's discretion.

EXPLORE – HOW DOES LIGHT TRAVEL?

In this lesson, students will analyze more properties of reflection, including angle of reflection, amount of reflection and absorption, diffusion, and refraction through various mediums. Some colors are brighter, some are darker. This lesson will allow students to use their observational skills to answer these and other questions based on reflection, absorption, transmission, and refraction of light.

If a laser is pointed at the mirror, what direction will it go? What colors are better at absorbing light? What causes diffusion of light? Can we bend light?

MATERIALS FOR STUDENTS

Per student: Explore Unit lab sheet

Per group: flashlight; laser pointer; mirror; protractor; straws; clear beaker* or glass* filled 2/3 with water*

*Items not included in TTI kit.

MATERIALS FOR TEACHER

None.

VOCABULARY (Building from engage)

Diffusion: scattering of light as it passes through a medium or is reflected from one.

Refraction: the bending of light as it passes through a medium.

TEACHER BACKGROUND

STUDENT ACTIVITY Explore-1: Angle of Reflection

Remind students of the dangers of shining laser pointers at each other. All lasers should have a clear path through a medium and to a target.

Students will measure the angle of reflection on a flat mirror to determine the path the light will travel. Students will shine the light from three different angles to the center of the protractor, collect data, analyze and draw conclusions on angles of reflection on the lab sheet. This activity is designed to discover that the angle of reflection is equal to the incident angle of light entering. While the actual angles of incident and reflection are measured from the normal line, or perpendicular 90° mark, this activity will still allow students to see that the light reflects from the mirror at the same angle it strikes the mirror. This works best in a semi-dark room with either clear protractors (supplied) or with markings drawn or taped along each angle to help the students shine accurately along each angle. This can be a bit difficult if the students move too much. Have them round to the nearest 10°.

Class Discussion Question: We can see the sign ahead because it is daytime. In rural areas, signs are placed 12 feet to the right of the road. At night, when a vehicle's headlights shine on a sign to the right of the road (click to show arrow going from headlight to sign), according to the angle of reflection where should the light end up going? (After some discussion, click to show arrow leaving sign). *As we approach the sign, the reflected light would travel away from the sign at the same angle our headlights struck the surface. This makes the sign difficult for the driver to see at night.* Where does the light need to go for driver to be able to see and read the sign at night? Why? *Back toward the driver. This is why sign material is engineered to retroreflect, or send light back in the direction of the vehicles.*

STUDENT ACTIVITY Explore-2: Diffusion

Students will shine a laser from a pointer through wrinkled clear plastic wrap to illustrate diffusion of light. What happens to the light as it passes through the medium? The light should scatter in many different ways and directions. In transportation, where would we see this occur: rain, snow, or fog?

Class Discussion Question: Why would you use your low beam (dim) headlights in fog rather than your high beam (bright) headlights? *This activity should help students understand diffusion of light. When light is diffused it scatters. The bright headlights will provide more light for the fog to scatter, making it too difficult for the driver to see the road. The dim headlights provide less light and shine slightly down, under the fog, making the markings on the road more visible.*

STUDENT ACTIVITY Explore-3: Refraction

Students will examine how light travels. They will view light reflecting from straws, as well as light from a laser pointer as they create images in beakers or clear drinking glasses containing water. What happens to the appearance of the straw in the water from different positions? What happens to the path of the light? This investigation illustrates refraction: how would you explain and define refraction? Refraction is the bending of light as it is changes speed. As it travels through different objects (the water), the light changes speed and turns as it slows down or speeds up. Rain on signs and pavement marking creates refraction, making them more difficult to see.

For best results, use 300 ml beakers filled with 200 ml of water or equivalent size clear glasses.

The angle of refraction changes with the interaction between the light and the particles in the medium including temperature and wavelength of the light. The light in these examples, as shown by the straw and the laser, bend when they pass through the center of the glass and even more as they pass through closer to the outside of the glass or beaker.

Class Discussion Question: In America, low beam headlights provide a distribution of light to illuminate the roadway in front of and to the right of the driver. There are limits on the amount of light that goes up and to the left. Why? *Vehicle headlights in America help the driver see road signs and pavement markings but prevent light from shining directly into the eyes of drivers in oncoming vehicles.* What about in countries where they drive on the other side of the road? *In countries where they drive on the left, their headlights would need to shine more to the left.*

STUDENT LAB SHEET – EXPLORE

A student lab sheet is available in the 5E format for use at the teacher's discretion.

EXPLAIN – CAN WE CHANGE WHAT WE SEE?

In this activity, students will investigate how glass spheres can change what we see and how they can help drivers see traffic signs at night.

What makes a sign more visible at night? What colors offer better reflection at night? What is retroreflection?

MATERIALS FOR STUDENTS

Per student: Explain Unit lab sheet.

Per group: clear, red, blue, yellow and green marble (one of each color); flashlight; white paper; black construction paper

MATERIALS FOR TEACHER

Glass sphere; laser pointer; white paper; foil; flashlight

VOCABULARY

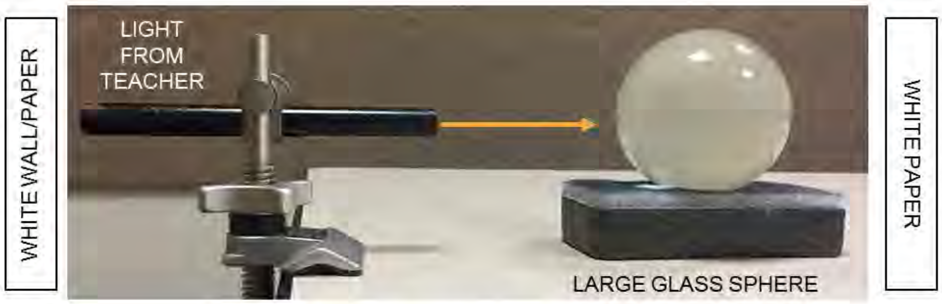
Retroreflection: light reflected back to its source with a minimum of scattering or diffused light.

TEACHER BACKGROUND:

TEACHER DEMONSTRATION: Explain-1: Light Through a Glass Sphere

When driving at night, we need signs to reflect light—not at the angle of reflection, but back toward the source in order for drivers to see the signs. We call this retroreflection. Retroreflection uses refraction and reflection to manipulate the light back toward the vehicle's headlights with some controlled diffusion.

Setup the laser and glass sphere as shown on the next page and in online demonstration. Ensure that there is a white surface (paper) behind the glass sphere and light source (wall or paper). Position yourself near the light source. Position students to the side of the demonstration; their view should be similar to the image on the next page. Make sure the path of the laser is visible to students, but from this angle there should be little to no actual light from the laser going toward the students. However, remind them not to look directly at the laser light. Shine the light such that the students can determine where the light goes as it passes through the sphere. Note: the light will scatter in various directions, so test before class to ensure students are positioned a safe distance away from the demonstration.



↑STUDENTS↑

Students will illustrate and describe three scenarios:

1. First, shine the flashlight at the sphere representing a vehicle's headlight.
2. Second, shine the laser pointer through the sphere.
3. Third, place a piece of foil in front of the white paper (you can wrap the foil around a file folder to make it sturdier) and again shine the laser light through the sphere.

The glass sphere will bend and reflect the light back toward you and the students. This is retroreflection. You can also wrap foil around the back half of the sphere to increase the effect, but you will need to use the flashlight rather than the laser as the reflected laser may be harmful to your eyes. Don't emphasize this last effect, as students will work to figure out this method in the next lesson. Refer back to the illustration on the lab sheet to verify that the students described retroreflection as light bouncing back toward the source.

STUDENT ACTIVITY: Explain-1: Does Color Matter?

Students discovered through the teacher demonstration that glass spheres can bend and reflect light in a way to create retroreflectivity. But does color matter? Students will place marbles of five different colors (one clear and four additional colors of their choice) onto a white or light colored surface, shine the flashlight into them, and record what they see. They will rank them from 1–5 on how brightly they reflect light.

Class Discussion Questions: Have students discuss this and then allow them time to try it out and see the results. Why did we place the marbles on a white or light colored surface? *The lighter color would not absorb the light from the flashlight but would instead allow it to reflect it back through the marble.*

What if we placed the marbles on a dark surface? Would it change how much light they reflect? *Yes, the darker surface would absorb much of the light, not allowing it to reflect back through the marble and to our eyes. This would make the marble appear much dimmer. While there is* *contrast, the idea here is for the kids to see that light behind and immediately surrounding the marble allows for better reflection of light. Later they may combine this concept with contrasting colors between words/symbols and the background of the sign.*

COOL FACT: The marbles light up and retroreflect much the same way as cat's eyes (or many other mammals) when a light shines on them in the dark! The marbles seem to be glowing, but really they are just retroreflecting!

VIDEO – RETROREFLECTIVITY: Retroreflective Materials: MAC RiAus PDplus

https://www.youtube.com/watch?v=rDRTmymuNyE

EXTENSION 1: MEASURING HEADLIGHTS AND CALCULATING AVERAGES

FROM THE HEADLIGHTS TO THE DRIVER'S EYES! This activity is recommended for 5th grade and above students and involves data collection and analysis using averages. Students will work in pairs or small groups.

Using a meter stick, have students gather data on 10 different vehicles from the teacher parking lot. Measure the height from the ground to the approximate center of the headlight. Allow each group to select and measure any 10 vehicles of their choosing and calculate the average height. Have the students record their findings and compute an average. Share and compare averages.

Class Discussion Questions: What makes a good sampling of vehicles? How do you know? Why could it be beneficial to get some measurements from many different types of vehicles? *A good sampling would include measurements from a variety of vehicles rather than the same type. Even further, the sampling should mimic the percentages of each type of vehicle on the road today.*

The average driver sits 1.1 meter or 110 cm above the roadway. Why is this an important number to know? *We need to know the average driver eye height so we can calculate the observation angle (angle between headlights and driver's eyes), which impacts the ability of drivers to see traffic signs.*

What role does retroreflection play for the driver to see this sign? *To see the sign,* ***retroreflection*** *must take place.*

What properties of light do we see happening in retroreflection? ***Retroreflection*** *is possible with the* ***emission and transmission*** *of the light to the sign followed by* ***refraction, reflection, diffusion*** *and even some* ***absorption*** *around the lettering. The truck needs slightly more diffusion so that the angle of observation is great enough that the light shines up to the driver. The sign will not work with reflection alone, which is where glass beads come in. We do not need absorption in the lettering or transmission through the sign for retroreflection.*

FUN FACTS IN TRANSPORTATION

The fun facts in transportation are located in the slide presentation.

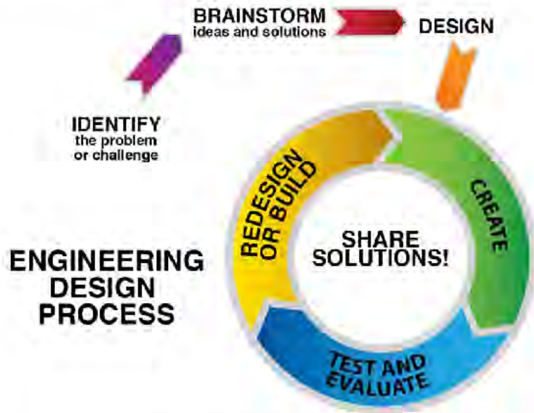
STUDENT LAB SHEET – EXPLAIN

A student lab sheet is available in the 5E format for use at the teacher's discretion.

ELABORATE – CAN WE CONTROL WHAT WE SEE?

In this activity, students will learn and use the engineering design process. They will design, construct, and test retroreflection on a traffic sign to maximize visibility at night to a driver.

What does it mean to be effective? What are constraints? What are criteria for success?



Engineering is about developing solutions to problems and challenges in our world. The Texas A&M Transportation Institute works every day toward solutions in all aspects of transportation. They conduct over 700 research projects each year on land, sea, and in the air.

The engineering design process is fluid. It does not have to begin or end at a particular point. One important aspect of the process is to share solutions along the way with others. Engineering is the design and building of new ideas.

Part 1a: Define the Problem (Team): What is it that you are trying to accomplish? On this challenge, we hope to achieve maximum retroreflection on a sign, so that it is easily visible to drivers at night.

Part 1b: Brainstorm (Individual): All ideas are a good idea at this stage. Here is where creativity is needed, and no reasonable idea is wrong or bad. This part of the process helps students use what they know and combine it with imagination.

Part 2: Design (Individual): Now it is time to work through all of the pros and cons of each idea. Here you will take into account the criteria, constraints, and materials you have available. Keep in mind the objective, what you are specifically trying to accomplish. At this point you will put your design

to paper with attention to each detail. Does it meet the proper criteria for success? Does it use only materials that are available?

Part 3a: Design (Team): Now it is time for the students to share their ideas with their team. They will need to analyze the best ideas and raise questions/concerns about ideas (in a respectful manner). The teams will combine their ideas into one design and draw it. Each team should also document the materials used. Remind them that they can only use materials from the original list.

Part 3b: Create (Team): The teams will create their signs.

Part 3C: Test and Evaluate (Team): The teams will test out their signs and evaluate the results. Each team will record their own positive (what worked well) and negative (what didn't work well) results. If Extension 2 is not used, each team can simply stand at the same location, turn off the lights, hold a flashlight up, and analyze their results. You can use two flashlights to mimic headlights. Make sure the signs and lights are in the same position for each presentation (height of the observer and sign matters).

Part 3D: Redesign (Team): The teams will think about how they would redesign their signs to solve any problems. Teams should document things they might change and why.

Part 3E: Share Success (Team): Share successful solutions with others. What are some features that the successful projects have in common? What was the best feature on your project? What was the best feature of another project? How could you combine them for even better results? If you had more time, or other resources, how could you improve on your sign?

MATERIALS FOR STUDENTS

Per student: Elaborate Unit lab sheet

Available per group: clear marbles; colored marbles (red, green, blue, and yellow); clay or Playdoh**; manila folders; construction paper; 1½ sheets of aluminum foil; rulers*; scissors*; glue*; clear tape*

*Items not included in TTI kit. **Item can be made by the teacher for use if preferred to clay.

SPECIAL NOTE TO TEACHER ON MATERIALS

1. Each student group will be allowed 12 marbles of any color.

2. Each group will use one manila folder for the base of their sign. They may add any of the other materials to the sign including various colors of construction paper.

3. If you prefer to make Playdoh rather than use the modeling clay provided, here is an easy recipe for teacher made Playdoh that makes 2 ½ cups:

- 2 cups plain flour (all purpose)
- 2 tablespoons vegetable oil

- 1/2 cup salt
- 2 tablespoons cream of tartar
- Up to 1.5 cups warm water (adding in increments)
- food coloring (optional, leave out for white)
- few drops glycerin

MATERIALS FOR TEACHER

Dark room*; flashlights on stand* or set spot (represents headlights); place to hang sign*

*Items not included in TTI kit.

VOCABULARY:

Effective: successful in producing the desired result.

Criteria: rule(s) or principle(s) for evaluation.

TEACHER BACKGROUND:

Here students will learn the engineering design process to design and construct a retroreflective sign. They will begin by defining the problem and then work toward a solution.

STUDENT ACTIVITY: Elaborate-1: Engineering Design Process Challenge

Students will put their understanding of the engineering design process to work by experimenting with a variety of ideas to make a sign with high retroreflective properties. All students should have the same criteria, constraints, and materials for each sign; however, they should be encouraged to use their imaginations as well. It is also a good idea to allow groups to work privately to provide for a greater number of original ideas when they share with the class. The challenge on the lab sheet simply calls for a directional sign. Some variations to their signs might be spacing of the marbles, depth of the marbles in the sign materials, color of the bead, the background of the sign behind the beads (e.g., plain, foil background, foil molded around the bottom portion of each marble prior to placement).

Each group: Share with the class the best thing about your model. Complete the lab sheet, writing down good ideas learned from other groups.

Class Discussion Question: What factors contributed the most to the retroreflectivity of the sign?

EXTENSION 2: BUILDING BETTER MODELS!

As a class or for each group, design a test car with flashlights for headlights and seats for the driver and front passenger. Use this model to measure the success of the retroreflection for each group's retroreflective sign. Ideas for construction include using chairs and tables, cardboard boxes or a combination of things already found in the classroom.

Make sure the model cars are far enough away that light can travel to the sign with enough room to retroreflect back to eyes of the drivers. Remember there are large, tall trucks on the road carrying heavy loads.

FUN FACTS IN TRANSPORTATION:

The fun facts in transportation are located in the slide presentation.

STUDENT LAB SHEET – ELABORATE

A student lab sheet is available in the 5E format for use at the teacher's discretion.

EVALUATE – CAN WE MAKE GOOD BETTER?

Students will be introduced to new technologies in retroreflection. Even when things work, we are always trying to find better solutions. At the Texas A&M Transportation Institute, we strive to develop new ways to improve the safety and mobility of the transportation system for all users. In this unit, students will compare various retroreflective materials to determine which technologies are the most effective, allowing drivers to see them in time to make safe driving decisions.

How can I collect data that is meaningful to my investigation? What factors should I consider when comparing the effectiveness of a product?

MATERIALS FOR STUDENTS

Per student: Evaluate Unit lab sheet; extra paper*

Per Group: sign sheeting materials (one piece each of #1, #2, and #3); flashlight; pocket microscope

*Items not included in TTI kit.

MATERIALS FOR TEACHER

Cube corner retroreflector; laser pointer (video alternative); bicycle reflector

VOCABULARY

Prismatic: having the form of a prism or collection of prisms

TEACHER BACKGROUND

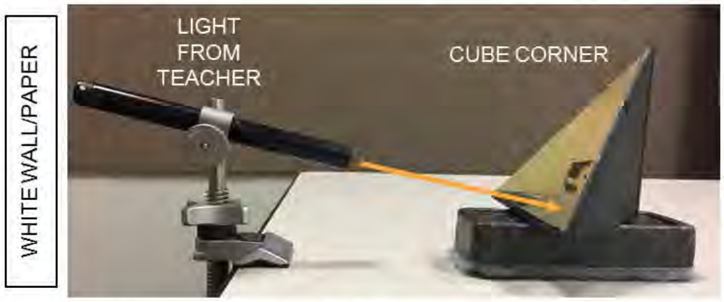
When driving, it is important to see and read signs with plenty of time to react. The type of retroreflective material affects the distance at which drivers can see and read signs. Increases in speed and mass of the vehicle require a longer stopping distance and thus drivers need to be able to see and read the signs from as far away as possible.

TEACHER DEMONSTRATION Evaluate-1: Prismatic Retroreflection

The teacher will show a brief video and/or conduct a demonstration using a laser pointer on a cube corner retroreflector to demonstrate how the prismatic retroreflectors work. This demonstration shows how light is reflected off multiple sides to reflect back toward the light source. You can also demonstrate the retroreflection of the bicycle reflector included in the kit by changing the angle of the flashlight.

Below is the link to a video that both explains retroreflective cubes and also provides some great visuals!

https://www.youtube.com/watch?v=S4vYq31cpyc



STUDENT ACTIVITY Evaluate-1: A Closer Look

Provide each student group with numbered sign sheeting material (#1, #2, and #3) and a pocket microscope. The students will describe and illustrate what they see through the microscope for each piece of sign sheeting material.

STUDENT ACTIVITY Evaluate-2: Test Engineering

In this activity, students will be challenged to set up their own investigation in order to recommend the most effective retroreflective materials based on their data from the first two activities as well as information collected and analyzed in an investigation of their own. The emphasis on this activity is each group's ability to design and carry out a relevant investigation. They will again follow the engineering design process to develop their investigation and will answer questions provided, as well as their own questions.

The sign sheeting material is all commercial-grade, so it is very bright at close distances making it difficult to tell them apart. Strategies to help students differentiate between the sign sheeting materials include: dimmer flashlights, further distances away from sign sheeting material, and creating overlays with construction paper that can be rotated in different directions (e.g., a letter or shape).



STUDENT ACTIVITY Evaluate-3: Share Solutions

They will share their investigation with the class through a brief presentation, relaying the test they designed along with their findings, analysis, and official recommendation for one of the retroreflective materials (1, 2, or 3). Presentations can vary from oral presentations only to more formal presentations with visual aids.

EXTENSION 3: Creating a Class Retroreflective Sign!

Let's put the A into STEM and move into STEAM! Using glass marbles or beads and/or prismatic materials from the consumable container of the TTI Retroreflection Kit, create a special retroreflective sign or keepsake for the classroom. Ideas include the school mascot, school initials, teacher's name, school name, logos, motivational wording, and more! Hang it up and enjoy! Please share a photo with us. Please would love to see what retroreflection looks like in your class!

FUN FACTS IN TRANSPORTATION

VIDEO Evaluate: The link is found below and also on the slides.

Here is an article and video about one of 3M's engineers who helped develop the retroreflectors of today. He has some great advice on perseverance and creativity when working on engineering projects.

"How the power of perseverance helped lead to a road safety breakthrough"

http://www.3m.com/3M/en_US/particles/all-articles/article-detail/~road-traffic-safety-reflective-signs-visibility?storyid=2cb8314f-358f-4924-800e-cc2b75191237&wt.z_ch=fb&wt.z_cp=applied_to_life&wt.z_mt=photo&wt.mc_id=road+safety2077

Additional fun facts in transportation are located in the slide presentation.

COOL FACT

VIDEO: Retroreflection on the moon!

This extra video shows how we use retroreflectors on the moon and a laser to see how far away the moon is from Earth at any given time! One of the testing facilities is here in Texas!

Mythbusters Moon Hoax Retroreflectors: https://www.youtube.com/watch?v=VmVxSFnjYCA

STUDENT LAB SHEET – EVALUATE

A student lab sheet is available in the 5E format for use at the teacher's discretion.

STANDARDS – NGSS AND TEXAS TEKS

NGSS: Next Generation Science Standards

Engineering Design:

3-5-ETS1-1. Define a simple design problem reflecting a need or want that includes specific criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

MS-ETS1-1. Define the criteria and constraints of a design problems with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Science and Engineering Practices:

Asking Questions and Defining Problems – Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.

Crosscutting Concepts – Influence of Engineering, Technology, and Science on Society and the Natural World People's needs and wants change over time, as do their demands for new and improved technologies. ***As traffic grows and speed limits rise, there is a greater need for more effective communication from traffic signs.*** (3- 5-ETS1-1)

Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. (3-5-ETS1-2) ***While there are effective traffic signs, improvement is still possible through new and innovative technologies and resources.***

EXPLORING the Science of RETROREFLECTIVITY

Disciplinary Core Ideas:

ETS1.B: Developing Possible Solutions – A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4) ***Prototypes and shared results between teams offer a wide range of new solutions.***

ETS1.C: Optimizing the Design Solution – Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each can provide useful information for the redesign process, that is, some of those characteristics may be incorporated into the new design (MS-ETS1-3) ***When several different options created and tested, engineers can use a multitude of the best results when creating a final, most effective product.***

GRADE SPECIFIC

GRADE 4

4-PS4-2. Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.

4-PS4-3. Generate and compare multiple solutions that use patterns to transfer information.

MIDDLE SCHOOL

MS-PS-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

Disciplinary Core Ideas

PS4.B Electromagnetic Radiation

When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2)

The path that light travels can be traced as straight lines, except at the surfaces between different transparent materials (e.g., water and air, air and glass) where the light path bends. (MS-PS4-2)

A wave model of light is useful for explaining brightness, color and the frequency-dependent bending of light at a surface between media. (MS-PS4.2)

Texas Essential Knowledge Standards (TEKS)

KNOWLEDGE AND SKILLS

GRADE 4

4.2. Scientific investigation and reasoning. The student uses scientific methods during laboratory and outdoor investigations. The student is expected to:

A. plan and implement descriptive investigations, including asking well-defined questions, making inferences, and selecting and using appropriate equipment or technologies to answer his/her questions;

B. collect and record data by observing and measuring, using the metric system, and using descriptive words and numerals such as labeled drawings, writing, and concept maps;

C. construct simple tables, charts, bar graphs, and maps using tools and current technology to organize, examine, and evaluate data;

D. analyze data and interpret patterns to construct reasonable explanations from data that can be observed and measured;

E. perform repeated investigations to increase the reliability of results; and

F. communicate valid oral and written results supported by data.

GRADE 5

5.2. Scientific investigation and reasoning. The student uses scientific methods during laboratory and outdoor investigations. The student is expected to:

A. describe, plan, and implement simple experimental investigations testing one variable;

B. ask well-defined questions, formulate testable hypothesis, and select and use appropriate equipment and technology;

C. collect information by detailed observations and accurate measuring;

D. analyze and interpret information to construct reasonable explanations from direct (observable) and indirect (inferred) evidence;

E. demonstrate that repeated investigations may increase the reliability of results;

F. communicate valid conclusions in both written and verbal forms; and

G. construct appropriate simple graphs, tables, maps and charts using technology, including computers, to organize, examine, and evaluate information.

GRADES 4 AND 5:

4.3 and 5.3: The student uses critical thinking and scientific problem solving to make informed decisions. The student is expected to:

A. in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observable testing, including examining all sides of scientific evidence of those scientific explanations to encourage critical thinking by the student.

D. connect grade-level appropriate science concepts with the history of science, science careers, and contributions of scientists.

4.4 and 5.4: The student knows how to use a variety of tools and methods to conduct science inquiry. The student is expected to:

A. collect, record, and analyze information using tools, including calculators, microscopes, cameras, computers, hand lenses, metric rulers, Celsius thermometers, mirrors, spring scales, pen balances, triple beam balances, graduated cylinders, beakers, hot plates, meter sticks, compasses, collecting nets, and notebooks; timing devices, including clocks and stopwatches; and materials to support observations of habitats or organisms such as terrariums and aquariums; and

B. use safety equipment, including safety goggles and gloves.

CONTENT SPECIFIC

GRADE 5

5.6.C: Demonstrate that light travels in a straight line until it strikes an object or travels through one medium to another and demonstrates that light can be reflected such as the use of mirrors or other shiny surfaces and refracted such as the appearance of an object when observed through water.

GRADE 6

5.2. Scientific investigation and reasoning. The student uses scientific inquiry methods during laboratory and field investigations. The student is expected to:

A. plan and implement comparative and descriptive investigations by making observations, asking well-defined questions, and using appropriate equipment and technology;

B. design and implement experimental investigations by making observations, asking well-defined questions, formulating testable hypotheses, and using appropriate equipment and technology;

C. collect and record data using the International System of Units (SI) and qualitative means such as labeled drawings, writing, and graphic organizers;

D. construct tables and graphs, using repeated trials and means, to organize data and identify patterns; and

E. analyze data to formulate reasonable explanations, communicate valid conclusions supported by the data, and predict trends.

5.3. Scientific investigation and reasoning. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions and knows the contributions of relevant scientists. The student is expected to:

A. in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations to encourage critical thinking by the student;

B. identify advantages and limitations of models such as size, scale, properties, and materials; and

C. relate the impact of research on scientific thought and society, including the history of science and contributions of scientists as related to the content.

Appendix B – Student Lab Worksheets and Key

Appendix B contains the student lab worksheets and the answer key.

STUDENT LAB SHEETS

Lab sheets are available for each lesson in the 5E format for use at the teacher's discretion.

The lesson is labeled in the top right corner of the first sheet. Ex: EXPLORE

Suggestions include:

- completion by students and inserted into science journal
- concepts, vocabulary, drawings, and information written into science journal
- use part or all of the lab sheets as content, time, and materials allow or are desired

EXPLORING the Science of RETROREFLECTIVITY

ENGAGE

What Do You See?

KEY VOCABULARY complete as you go

emission of light:

transmission of light:

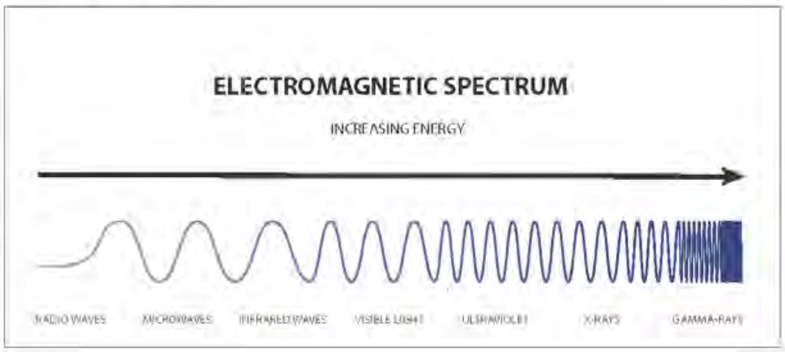
absorption of light:

Light is **emitted** from a source. The white light comes in contact with objects. Some objects **transmit** the light or let it shine right through, such as clear plastic or the glasses you put on. Some objects take in the light and change the energy into heat. This is known as **absorption**. Other objects bounce the light right off a surface. We call this reflection. Many objects do a bit of all of these. When we look at objects we see what color or colors are reflected to our eyes. Since all colors are contained in white light, objects that appear white to our eyes bounce back all the colors together and we see white.

When we look at a ripe banana, all of the colors shine on the banana. The banana absorbs all the colors (ROYGBIV) except yellow. Yellow reflects back to our eyes and we see a yellow banana. **Using this logic, explain to a partner why plants are green.**

How Does Light Travel?

The sun emits energy in the form of waves. These waves travel through space at the speed of light and make up the electromagnetic spectrum. Each type of wave has a different wavelength (the distance between each wave). As the distance between the waves gets smaller, the energy of the wave increases because there are more waves in a shorter amount of time. Within these different wavelengths is a special group of waves called visible light. This light is what allows us to see all the objects around us. The other waves in the electromagnetic spectrum are invisible to our eyes but are able to be detected using specialized equipment.



1. Which waves have the most energy?

2. Where is visible light located on the electromagnetic spectrum above? What does this tell us about its energy?

3. What other waves have you heard of on the electromagnetic spectrum? List them below and then share out loud with a partner or the class what you know about each.

SAFE-D Texas A&M Transportation Institute EXPLORING the Science of RETROREFLECTIVITY

TEACHER DEMONSTRATION **RAINBOW OF LIGHT**

Based on your observations, answer the following questions.

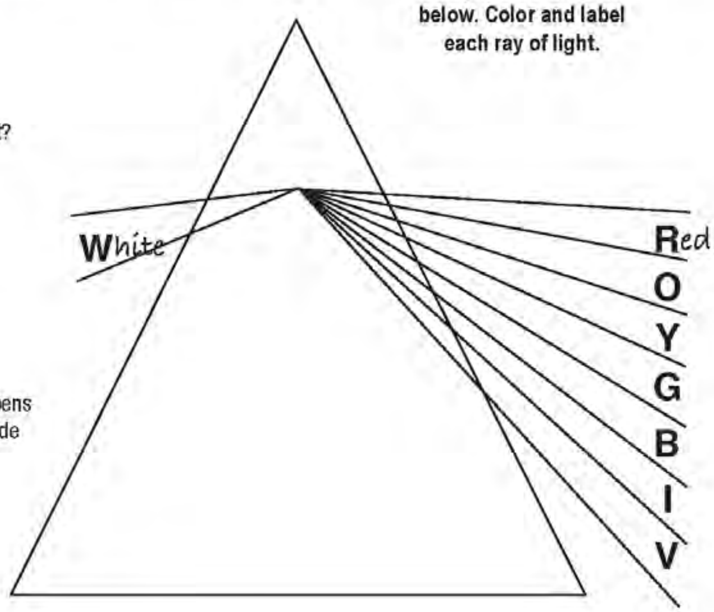
1. What is visible light?

2. List three objects that produce and emit light?

3. What color does light appear to be?

4. We call natural light "white light". What happens to the white light as it shines out the other side of the prism?

Complete the diagram below. Color and label each ray of light.



STUDENT ACTIVITY - 1

RAINBOW GLASSES

Using the rainbow glasses provided in the kit, look into the lights around your classroom.

1. Pick your favorite light pattern. In the box, illustrate and describe what patterns and colors you see.

2. The glasses tell you about the lights that shine around you. How is it different than looking just with your eyes?

DRAW AND EXPLAIN HERE:

STUDENT ACTIVITY - 2 COMPARISON OF COLORS, REFLECTION, AND ABSORPTION

Place the pieces of construction paper on the desk or table in front of you. With the lights off, shine the flashlight on the center of each color and rank the colored paper from brightest (1) to the least bright or dimmest (4).

PAPER COLOR	WAS MORE LIGHT ABSORBED OR MORE LIGHT REFLECTED?	RANK

1. Does absorption or reflection make an object appear brighter? Explain your thoughts.

2. If objects that absorb light convert the light energy to heat energy, which color object would absorb the most light and increase in temperature most easily: black or yellow? Explain your answer.

3. In conclusion, explain how reflection and absorption determine which colors we see and how bright a color appears to our eyes. You may use an example to help explain your answer.

EXPLORE

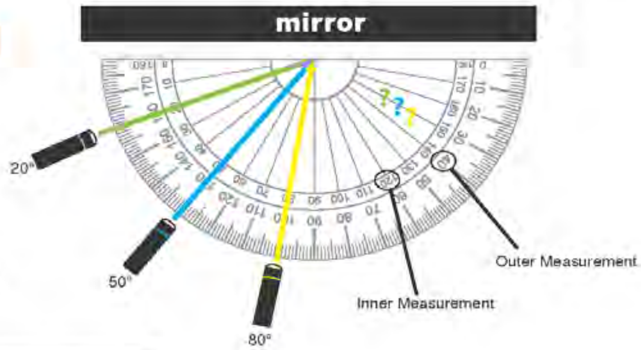
How does light travel?

Light travels on waves in a straight line at the speed of light, 300,000 kilometers per second, through space. As light travels or is transmitted or moves through other materials the light is slowed down. Sometimes the light bends, or is refracted. Other times it is reflected, absorbed or diffused. Some objects are better at reflecting light, others are better at absorbing light. Let's explore some materials and see where the light goes!

STUDENT ACTIVITY - 1

ANGLE OF REFLECTION

Let's see if we can figure out what the angle of reflection is by doing a test. We will be shining the laser at an angle of 20°, 50°, and 80°, where do you think the light will go? Fill in below. With the protractor sitting against a standing mirror, shine the laser down the left side using the inner measurements. While one team member holds the laser steady have another team member measure the angle of the reflected laser on the right using the outer angles. **Draw lines on the diagram to the right to show where your light travels each time. Round to the nearest 10 degrees. Also, fill in below.**



	HYPOTHESIS	OBSERVED
20°		
50°		
80°		

CONCLUSION:

1. Is the angle that light hits and reflects the same or different?

2. If you were to shine your headlights on a street sign that is off to your right, where do you think the light would go?

3. Would it be easy or difficult to see that sign at night? **Explain.**

SAFE-D Texas A&M Transportation Institute EXPLORING the Science of RETROREFLECTIVITY

STUDENT ACTIVITY - 2 DIFFUSION

Take a piece of clear plastic wrap. Wad it up into a ball so that it stays together, but not too tight. Hold it a few inches above the surface of the table. Shine the laser pointer into the top from about 2-3 inces above. Answer questions about where the light goes below:

Draw arrows to show light everywhere you see it after it hits the plastic.

1. Is any light reflected off the plastic?

2. Is any of the light absorbed?

3. Is any light transmitted through the plastic to the table?

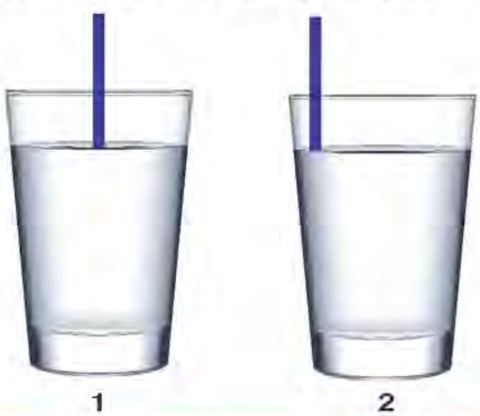
4. This investigation demonstrates DIFFUSION. Based on your observations, how would you define diffusion?

5. How would diffusion of light be helpful or harmful in transportation? Explain your thinking.

STUDENT ACTIVITY - 3 REFRACTION

Using a 300ml beaker or clear drinking glasses, fill it 2/3 with water. First place a straw in the middle of the glass.

Looking beside the glass from the front, draw what you see in the water below. Repeat for number 2, placing the straw closer to the edge of the glass.



Describe what you see in each glass.

1. Glass #1:

2. Glass #2:

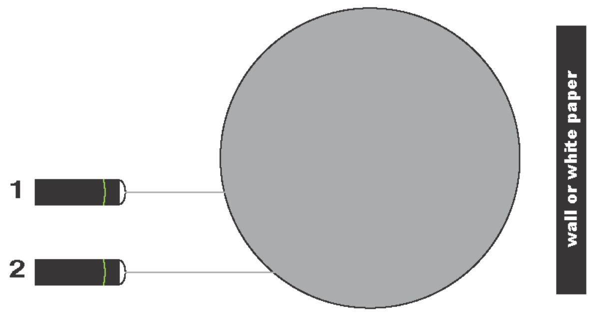
3. What do both paths have in common?

4. Which path shows the greatest difference from the actual straw? Explain.

STUDENT ACTIVITY - 3 REFRACTION CONTINUED

Shine a laser light through the liquid and look through the top of the glass. First shine the light through the middle and then through closer to the side.

Draw the path of the laser light for each below.



Describe what you see in each glass above.

1. Laser #1:

2. Laser #2:

3. What do both paths have in common?

4. Which shows the greatest difference from the entry light? **Explain.**

REFRACTION refers to the bending of light. Based on your above observations, answer the following questions.

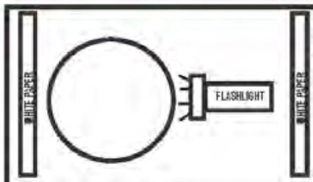
1. Did light from the straw and the laser bend more or less when closer to the outside curved surface of the glass?

2. If water bends light, where or how might what a driver sees change in the rain or snow?

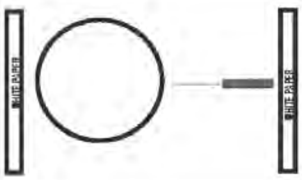
Can we change what we see?

EXPLAIN

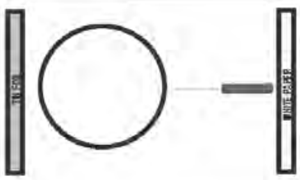
TEACHER DEMONSTRATION LIGHT THROUGH A GLASS SPHERE



1. Where does the light from the flashlight go as it is transmitted through the glass ball? Illustrate and describe.



2. Where does the light from the laser go as it is transmitted through the glass ball? Illustrate and describe.

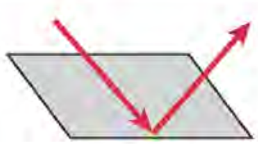


3. When metal is placed behind the glass ball, does this change what you see from the laser pointer? Illustrate and describe.

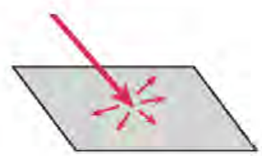
What happens when the teacher wraps the foil on the back of the glass sphere?

When people drive their vehicles they need to be able to see signs that are high in the air and on the side of the road. For this to happen we need to combine reflection, refraction and diffusion so that the light from the headlights returns to the vehicle.

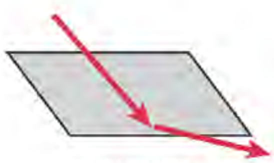
Briefly describe what the light is doing in each picture.



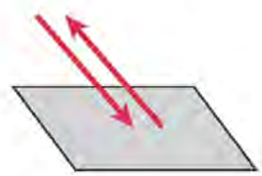
REFLECTION



DIFFUSION



REFRACTION



RETROREFLECTION

EXPLORING the Science of RETROREFLECTIVITY

SAFE-D Texas A&M Transportation Institute

RETROREFLECTION combines reflection with refraction and some diffusion to help drivers better see road signs.
Based on your observations, describe how retroreflection works.

STUDENT ACTIVITY - 1 **DOES COLOR MATTER?**

Place the five various colored marbles on a white or light colored surface. Holding the flashlight in front of your chin, shine the light at each marble and record what you see. Describe how the light retroreflected with each color and rate them 1-5, brightest=1, dimmest=5.

COLOR:	COLOR 1:	COLOR 2:	COLOR 3:	COLOR 4:
CLEAR				
RANK	RANK	RANK	RANK	RANK

ELABORATE

Can we control what we see?

Engineering is about developing new solutions to problems and challenges in our world. The Texas A&M Transportation Institute works every day towards solutions in all aspects of transportation. They conduct over 700 research projects each year on the land, sea and in the air.

The engineering design process is fluid. It does not have to begin or end at a particular point. One important aspect of the process is to share solutions along the way with others. Engineering is the design and building of new ideas.

TEAM CHALLENGE:

SIGN

Design and build a directional sign to achieve maximum retroreflection to the driver with headlights at night.

MATERIALS:

12 marbles
clay or play-doh
rulers
foil
8"x 11" manila folder
construction paper
scissors
glue
clear tape

KEY VOCABULARY

As a class, define each of the following words and determine how they are important components of engineering.

effective:

criteria:

EXPLORING the Science of RETROREFLECTIVITY

STUDENT ACTIVITY - 1 ENGINEERING DESIGN PROCESS CHALLENGE!

PART I: DEFINE THE PROBLEM OR CHALLENGE

With your **team**, state your challenge. **What is it that you are trying to accomplish? Decide this as a group.**

ONCE YOU HAVE DEFINED THE PROBLEM OR CHALLENGE AS A TEAM, YOU WILL WORK ALONE ON THE NEXT TWO STEPS!

BRAINSTORM: ALL ideas are good ideas at this stage. Here is where creativity is needed and no reasonable idea is bad or wrong. This part of the process helps us use what we know and combine it with imagination. Did you ever hear the saying, " two heads are better than one?" Well here EACH team member should come up with their own idea or ideas to share with the group. **Work independently and write down all your ideas here.**

EXPLORING the Science of RETROREFLECTIVITY

PART 2: DESIGN

INDIVIDUAL: Continue to work alone to complete your design. Now it is time to work through all of the pros and cons of each idea. Here you will design a sign that tells drivers to turn right. You can use pictures or words or both on your sign. Make sure your sign fulfills the criteria and uses only the materials allowed. This design is your very own idea that you will share with the group after completing your design and answering the first two questions below. Be creative.

YOUR PERSONAL IDEA FOR THE SIGN

What do you like best about your personal idea? Why?

What do you have the most concern about your personal idea? Explain.

PART 3: TEAM DESIGN

With your team, design again. Combine each member's design into one so that you maximize your great ideas for a successful design that meets the criteria. Be very detailed in your drawing and label all items. While not every idea will be a part of the team sign, all ideas help generate solutions. Part of the engineering design process is working through ideas to find the best solutions to the problem. 3M Engineer Tim Hoopman said, "Be a risk taker. Let your failures be your education and your successes be your legacy."

TEAM SIGN DESIGN (everyone should have the same sign here)

MATERIALS LIST:

Be very specific, ex: 3 red marbles. Remember you can ONLY use materials from the original list.

CREATE: Make a sign using the team's best ideas.

TEST & EVALUATE: Test out your sign and evaluate the results. Record all positive and negative results.

REDESIGN: Redesign to solve any problems with your sign. Document some things you might change to the design. Did you consider varying the depth of marbles, adjusting the spacing between marbles, or changing what is behind each marble or marbles?

FINAL TEAM SIGN DESIGN

SHARE SUCCESS:

Share successful solutions with the class, not only the finished product, but the steps you took along the way.

What are some features that successful projects have in common?

What was the best retroreflective feature on your project? Why?

What was the best retroreflective feature of another project? Why?

How could we combine all the team's best work for even better retroreflective results?

If you had more time, or other resources, how could you improve on your sign?

Can we make good better?

EVALUATE

STUDENT ACTIVITY - 1 **A CLOSER LOOK!**

Using the pocket microscope, look at each piece of sign sheeting material more closely. **Describe and illustrate what you see for each.**

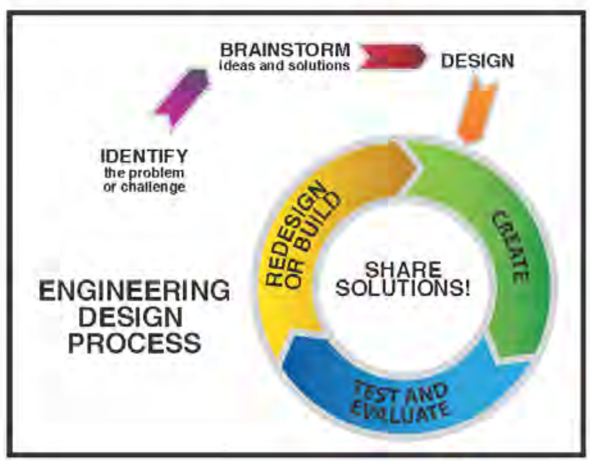
1	2	3

STUDENT ACTIVITY - 2 **TEST ENGINEERING**

As vehicles travel on our roads, some travel more slowly through neighborhoods or school crossings, while those traveling on the highways are going much faster. As you go faster, is it harder or easier to stop? Before answering, try this quick test. Walk around the classroom at a normal pace. Have someone in your group tell you when to stop. Have the others watch to see how quickly you are able to come to a complete stop. Next find a clear space that your teacher will allow you to run. Take off as fast as you can and again have someone in your group tell you when to stop and have the others observe. Discuss this quick investigation as a group to determine your results. Was it easier to stop quickly from a walk or a run? **Explain your reasoning.**

Now imagine vehicles on the roads, going slow and going fast. The important thing about traffic signs are that drivers are able to see and read them in time to follow them. Which of the reflective materials would allow drivers to read a sign sooner? In order to recommend one of these products you will need to use all of your prior investigative knowledge, as well as design an investigation to provide evidence that supports your recommendation with scientific proof.

Your group will act as test engineers on this activity. Test engineers design experiments they can test on products in order to assure they meet their requirements. You will be using the engineering design process to conduct your investigation. Rather than engineer a product, you will engineer a method of testing a product to verify its effectiveness to retroreflect.



SAFE-D Texas A&M Transportation Institute EXPLORING the Science of RETROREFLECTIVITY

IDENTIFY the problem or challenge. What is the problem you are working to solve or question you are trying to answer?

BRAINSTORM ways to solve the problem. What are some methods you could use to test the materials. Remember all ideas are worth writing down and considering!

DESIGN your investigation. After discussing your ideas, narrow your investigation down to the investigation that will give you answers that will best help you solve your problem. Describe your investigation design in detail.

CREATE your investigation. Set everything up and prepare to investigate!

TEST AND EVALUATE! Conduct your investigation and record ALL observations, data, and more below. Draw any data charts, graphs and more you will be using to collect and analyze your data. Use a separate piece of paper as needed.

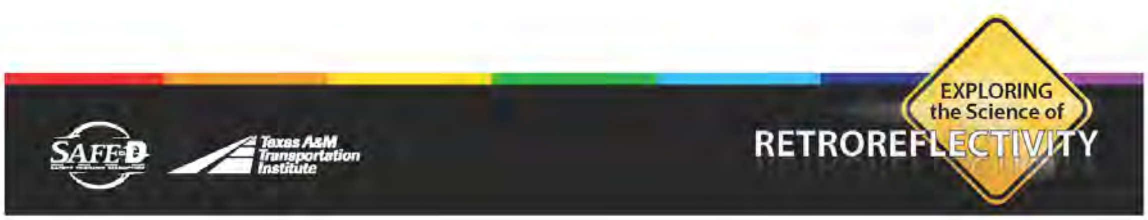
STUDENT LAB SHEETS

Lab sheets are available for each lesson in the 5E format for use at the teacher's discretion.

The lesson is labeled in the top right corner of the first sheet. Ex: EXPLORE

Suggestions include:

- completion by students and inserted into science journal
- concepts, vocabulary, drawings, and information written into science journal
- use part or all of the lab sheets as content, time, and materials allow or are desired



What Do You See?

ENGAGE

KEY VOCABULARY complete as you go

emission of light: generating and putting out light

transmission of light: movement of light through a medium

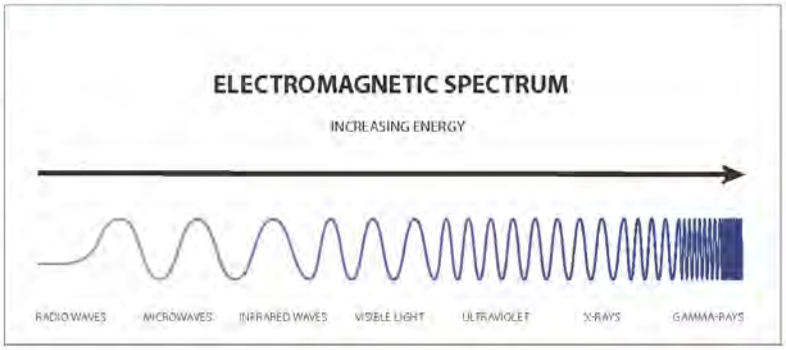
absorption of light: taking in and holding light

Light is **emitted** from a source. The white light comes in contact with objects. Some objects **transmit** the light or let it shine right through, such as clear plastic or the glasses you put on. Some objects take in the light and change the energy into heat. This is known as **absorption**. Other objects bounce the light right off a surface. We call this reflection. Many objects do a bit of all of these. When we look at objects we see what color or colors are reflected to our eyes. Since all colors are contained in white light, objects that appear white to our eyes bounce back all the colors together and we see white.

When we look at a ripe banana, all of the colors shine on the banana. The banana absorbs all the colors (ROYGBIV) except yellow. Yellow reflects back to our eyes and we see a yellow banana. **Using this logic, explain to a partner why plants are green.**
Plants absorb all colors except for green and reflect green back.

How Does Light Travel?

The sun emits energy in the form of waves. These waves travel through space at the speed of light and make up the electromagnetic spectrum. Each type of wave has a different wavelength (the distance between each wave). As the distance between the waves gets smaller, the energy of the wave increases because there are more waves in a shorter amount of time. Within these different wavelengths is a special group of waves called visible light. This light is what allows us to see all the objects around us. The other waves in the electromagnetic spectrum are invisible to our eyes but are able to be detected using specialized equipment.



1. Which waves have the most energy?
   Gamma rays

2. Where is visible light located on the electromagnetic spectrum above?
   Middle
   What does this tell us about its energy?
   Example: More energy than microwave, but less energy than x-rays.

3. What other waves have you heard of on the electromagnetic spectrum? List them below and then share out loud with a partner or the class what you know about each.

EXPLORING the Science of RETROREFLECTIVITY

TEACHER DEMONSTRATION **RAINBOW OF LIGHT**

Based on your observations, answer the following questions.

1. What is visible light?

Visible light is a combination of red, orange, yellow, green, blue, indigo and violet that we see combined.

2. List three objects that produce and emit light?

Some examples are the sun, light bulbs, tv screens, computer screens. Basically anything that generates and puts out it's own light.
Note: Not the moon, it is reflected light.

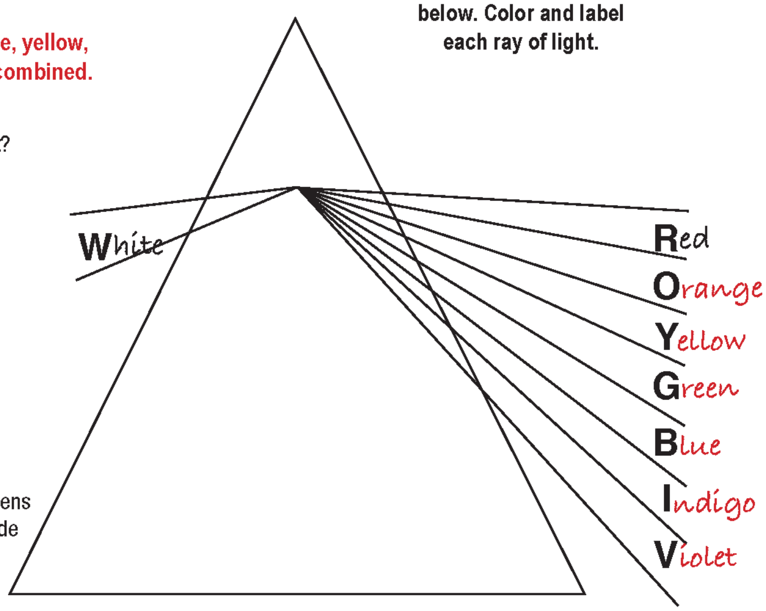
3. What color does light appear to be?

White

4. We call natural light "white light". What happens to the white light as it shines out the other side of the prism?

Shows ROYGBIV

Complete the diagram below. Color and label each ray of light.



STUDENT ACTIVITY - 1

RAINBOW GLASSES

Using the rainbow glasses provided in the kit, look into the lights around your classroom.

1. Pick your favorite light pattern. In the box, illustrate and describe what patterns and colors you see.

2. The glasses tell you about the lights that shine around you. How is it different than looking just with your eyes?

The glasses show the ROYGBIV, but without them on you just see the white light.

DRAW AND EXPLAIN HERE:

STUDENT ACTIVITY - 2 COMPARISON OF COLORS, REFLECTION, AND ABSORPTION

Place the pieces of construction paper on the desk or table in front of you. With the lights off, shine the flashlight on the center of each color and rank the colored paper from brightest (1) to the least bright or dimmest (4).

PAPER COLOR	WAS MORE LIGHT ABSORBED OR MORE LIGHT REFLECTED?	RANK
blue	More light seems to be absorbed, less reflected, dim blue.	
red	More light seems to be absorbed, less reflected, dim red.	
yellow	Less light seems to be absorbed, more reflected, bright.	
black	Almost all the light is absorbed, very little reflected, dim.	

1. Does absorption or reflection make an object appear brighter? Explain your thoughts.

Reflection. If the darker colors are absorbed and the lighter colors are reflected the brighter the objects will appear.

2. If objects that absorb light convert the light energy to heat energy, which color object would absorb the most light and increase in temperature most easily: black or yellow? Explain your answer.

Black would absorb the most light energy and then convert it to heat energy, becoming hotter than a similar but yellow object.

3. In conclusion, explain how reflection and absorption determine which colors we see and how bright a color appears to our eyes. You may use an example to help explain your answer.

Colors that are absorbed are not visible to our eyes, but those reflected are. If only one color, such as blue is reflected, then the object will appear blue while a combination of colors reflected such as blue and green might appear aqua blue, a combination of colors.

EXPLORE

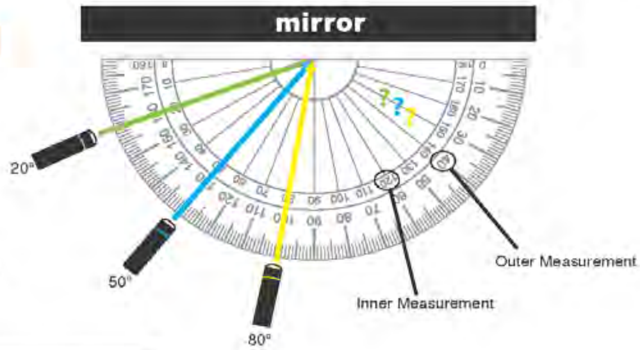
How does light travel?

Light travels on waves in a straight line at the speed of light, 300,000 kilometers per second, through space. As light travels or is transmitted or moves through other materials the light is slowed down. Sometimes the light bends, or is refracted. Other times it is reflected, absorbed or diffused. Some objects are better at reflecting light, others are better at absorbing light. Let's explore some materials and see where the light goes!

STUDENT ACTIVITY - 1

ANGLE OF REFLECTION

Let's see if we can figure out what the angle of reflection is by doing a test. We will be shining the laser at an angle of 20°, 50°, and 80°, where do you think the light will go? Fill in below. With the protractor sitting against a standing mirror, shine the laser down the left side using the inner measurements. While one team member holds the laser steady have another team member measure the angle of the reflected laser on the right using the outer angles. **Draw lines on the diagram to the right to show where your light travels each time. Round to the nearest 10 degrees. Also, fill in below.**



	HYPOTHESIS	OBSERVED
20°		
50°		
80°		

CONCLUSION:

1. Is the angle that light hits and reflects the same or different?

The same, 20 degrees in equals 20 degrees out.

2. If you were to shine your headlights on a street sign that is off to your right, where do you think the light would go?

Further off to the right at the same angle it came in from.

3. Would it be easy or difficult to see that sign at night? **Explain.**

You would not see the reflected light. It would reflect out of sight.

EXPLORING the Science of RETROREFLECTIVITY

STUDENT ACTIVITY - 2 DIFFUSION

Take a piece of clear plastic wrap. Wad it up into a ball so that it stays together, but not too tight. Hold it a few inches above the surface of the table. Shine the laser pointer into the top from about 2-3 inces above. Answer questions about where the light goes below:

1. Is any light reflected off the plastic?

   Yes, some of the light reflects off of the plastic.

2. Is any of the light absorbed?

   Some of the light is absorbed and trapped inside the ball of plastic.

3. Is any light transmitted through the plastic to the table?

   Yes, there is light that passes through to the table.

4. This investigation demonstrates DIFFUSION. Based on your observations, how would you define diffusion?

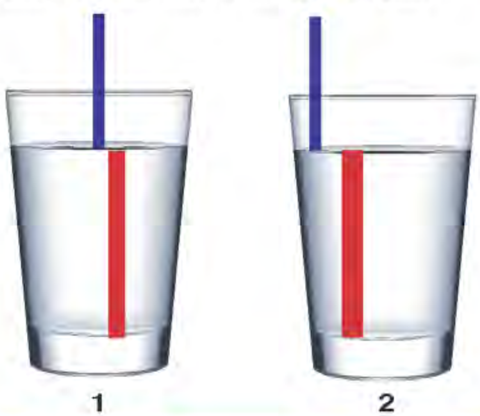
   Diffusion is the scattering of light in many different directions.

Draw arrows to show light everywhere you see it after it hits the plastic.

STUDENT ACTIVITY - 3 REFRACTION

Using a 300ml beaker or clear drinking glasses, fill it 2/3 with water. First place a straw in the middle of the glass.

Looking beside the glass from the front, draw what you see in the water below. Repeat for number 2, placing the straw closer to the edge of the glass.



Describe what you see in each glass.

1. Glass #1:

   The bottom of the straw appears as a separated line from the straw above the waterline and larger under water.

2. Glass #2:

   The bottom of the straw appears as a separated line from the straw above the water line and larger under the water. There is more of a gap between the two lines.

3. What do both paths have in common?

   Both lines are separated and larger under the waterline.

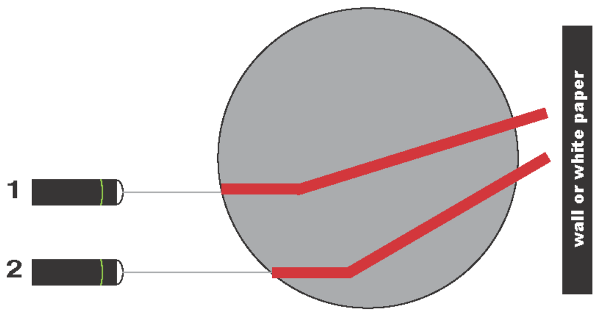
4. Which path shows the greatest difference from the actual straw? **Explain.**

   The bottom straw in glass number 2 appears further separated from the top straw and the straw in glass number 2 appears larger.

STUDENT ACTIVITY - 3 REFRACTION CONTINUED

Shine a laser light through the liquid and look through the top of the glass. First shine the light through the middle and then through closer to the side.

Draw the path of the laser light for each below.



Describe what you see in each glass above.

1. Laser #1:

There is refraction, the light bends through the middle.

2. Laser #2:

There is refraction, the light bends more through the middle.

3. What do both paths have in common?

Both show refraction of the laser light as it passes through the water.

4. Which shows the greatest difference from the entry light? **Explain.**

The path that begins closer to the outside of the beaker (#2) has a greater amount of refraction than the one in the middle (#1).

REFRACTION refers to the bending of light. Based on your above observations, answer the following questions.

1. Did light from the straw and the laser bend more or less when closer to the outside curved surface of the glass?

The laser bends more when the straw and the laser are closer to the outside. The water and the glass were at a more curved angle and thus bent the light with a greater angle.

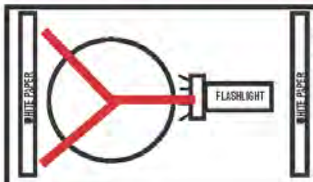
2. If water bends light, where or how might what a driver sees change in the rain or snow?

In the rain or snow, the drops or flakes will also refract and diffuse light as it passes through the precipitation.

EXPLAIN

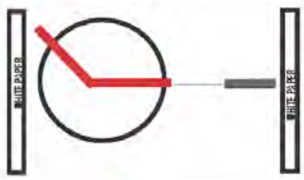
Can we change what we see?

TEACHER DEMONSTRATION **LIGHT THROUGH A GLASS SPHERE**



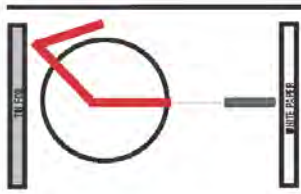
1. Where does the light from the flashlight go as it is transmitted through the glass ball? Illustrate and describe.

The light is transferred through the glass sphere. The light refracts as it passes through the sphere. The light is also diffused onto the white paper in front of it.



2. Where does the light from the laser go as it is transmitted through the glass ball? Illustrate and describe.

The light is transferred through the glass sphere. The light refracts as it passes through the sphere. The light also shines on the white paper in front of it; less diffusion.



3. When metal is placed behind the glass ball, does this change what you see from the laser pointer? Illustrate and describe.

The light is transferred through the glass sphere. The light refracts as it passes through the sphere. The light shining on the tin foil is reflected off at the same angle it strikes at.

What happens when the teacher wraps the foil on the back of the glass sphere?

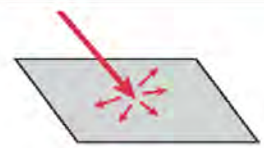
With the tin foil wrapped around the sphere, the light from the laser is refracted and reflected back to the light source (onto the white paper). The wrapped tin foil helps direct and control where the light goes. It retroreflects.

When people drive their vehicles they need to be able to see signs that are high in the air and on the side of the road. For this to happen we need to combine reflection, refraction and diffusion so that the light from the headlights returns to the vehicle.

Briefly describe what the light is doing in each picture.

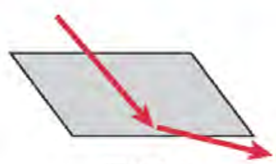
REFLECTION

The light bounces off the surface at the same but opposite angle of entrance.



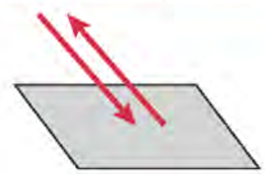
DIFFUSION

Light is transferred through and reflected off of the material and scatters.



REFRACTION

As the light is transferred through the item, it bends.



RETROREFLECTION

Light is reflected off the surface and back to the source using reflection and refraction.

EXPLORING the Science of RETROREFLECTIVITY

RETROREFLECTION combines reflection with refraction and some diffusion to help drivers better see road signs.
Based on your observations, describe how retroreflection works.

Retroreflection is when light is reflected and refracted in a way that the light is returned towards the source.

STUDENT ACTIVITY - 1 **DOES COLOR MATTER?**

Place the five various colored marbles on a white or light colored surface. Holding the flashlight in front of your chin, shine the light at each marble and record what you see. Describe how the light retroreflected with each color and rate them 1-5, brightest=1, dimmest=5.

COLOR:	COLOR 1:	COLOR 2:	COLOR 3:	COLOR 4:
CLEAR				
RANK	RANK	RANK	RANK	RANK
1	Light colors rank 2-3 while darker colors will rank 4-5.			

ELABORATE

Can we control what we see?

Engineering is about developing new solutions to problems and challenges in our world. The Texas A&M Transportation Institute works every day towards solutions in all aspects of transportation. They conduct over 700 research projects each year on the land, sea and in the air.

The engineering design process is fluid. It does not have to begin or end at a particular point. One important aspect of the process is to share solutions along the way with others. Engineering is the design and building of new ideas.

TEAM CHALLENGE:

Design and build a directional sign to achieve maximum retroreflection to the driver with headlights at night.

MATERIALS:
12 marbles
clay or play-doh
rulers
foil
8"x 11" manila folder
construction paper
scissors
glue
clear tape

KEY VOCABULARY

As a class, define each of the following words and determine how they are important components of engineering.

effective: **When the product actually does what it was intended to do.**

criteria: **The specifications to which a product is designed. What it needs to have and what it must do.**

EXPLORING the Science of RETROREFLECTIVITY

STUDENT ACTIVITY - 1 ENGINEERING DESIGN PROCESS CHALLENGE!

PART I: DEFINE THE PROBLEM OR CHALLENGE

With your **team**, state your challenge. **What is it that you are trying to accomplish? Decide this as a group.**

ONCE YOU HAVE DEFINED THE PROBLEM OR CHALLENGE AS A TEAM, YOU WILL WORK ALONE ON THE NEXT TWO STEPS!

BRAINSTORM: ALL ideas are good ideas at this stage. Here is where creativity is needed and no reasonable idea is bad or wrong. This part of the process helps us use what we know and combine it with imagination. Did you ever hear the saying, " two heads are better than one?" Well here EACH team member should come up with their own idea or ideas to share with the group. **Work independently and write down all your ideas here.**

Anything within reason and specific to the task at hand.

PART 2: DESIGN

INDIVIDUAL: Continue to work alone to complete your design. Now it is time to work through all of the pros and cons of each idea. Here you will design a sign that tells drivers to turn right. You can use pictures or words or both on your sign. Make sure your sign fulfills the criteria and uses only the materials allowed. This design is your very own idea that you will share with the group after completing your design and answering the first two questions below. Be creative.

YOUR PERSONAL IDEA FOR THE SIGN

For this section, students must be specific in their design.
Make sure they include colors, number of marbles, foil if needed, etc.

What do you like best about your personal idea? Why?

What do you have the most concern about your personal idea? Explain.

PART 3: TEAM DESIGN

With your team, design again. Combine each member's design into one so that you maximize your great ideas for a successful design that meets the criteria. Be very detailed in your drawing and label all items. While not every idea will be a part of the team sign, all ideas help generate solutions. Part of the engineering design process is working through ideas to find the best solutions to the problem. 3M Engineer Tim Hoopman said, "Be a risk taker. Let your failures be your education and your successes be your legacy."

TEAM SIGN DESIGN (everyone should have the same sign here)

For this section, students must be specific in their design.
Make sure they include colors for each part/material,
number and color of marbles, foil if needed, drawn to scale, etc.

MATERIALS LIST:

Be very specific, ex: 3 red marbles. Remember you can ONLY use materials from the original list.

CREATE: **Make a sign using the team's best ideas.**

TEST & EVALUATE: **Test out your sign and evaluate the results. Record all positive and negative results.**

REDESIGN: Redesign to solve any problems with your sign. Document some things you might change to the design. Did you consider varying the depth of marbles, adjusting the spacing between marbles, or changing what is behind each marble or marbles?

FINAL TEAM SIGN DESIGN

For this section, students must be specific in their design.
Make sure they include colors for each part/material,
number and color of marbles, foil if needed, drawn to scale, etc.

SHARE SUCCESS:

Share successful solutions with the class, not only the finished product, but the steps you took along the way.

What are some features that successful projects have in common?

Most likely they will have clear marbles with foil wrapped or in place behind the marble surrounded by a dark background for contrast. They will have a clear, easy to read, and understandable message.

What was the best retroreflective feature on your project? Why?

Should be the clear marbles, so long as they had a shiny backdrop or foil wrapped on backside of the marble.

What was the best retroreflective feature of another project? Why?

Contrast is another factor that contributes to a good sign, as well as clear message.

How could we combine all the team's best work for even better retroreflective results?

Here the class will choose a feature from each sign and combine them into one sign.

If you had more time, or other resources, how could you improve on your sign?

Here students will likely add features and techniques they learned from other groups.

Can we make good better?

EVALUATE

STUDENT ACTIVITY - 1 **A CLOSER LOOK!**

Using the pocket microscope, look at each piece of sign sheeting material more closely. **Describe and illustrate what you see for each.**

1

2

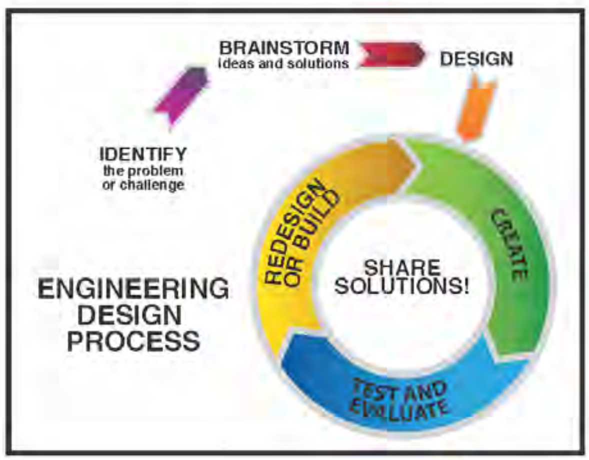
3

STUDENT ACTIVITY - 2 **TEST ENGINEERING**

As vehicles travel on our roads, some travel more slowly through neighborhoods or school crossings, while those traveling on the highways are going much faster. As you go faster, is it harder or easier to stop? Before answering, try this quick test. Walk around the classroom at a normal pace. Have someone in your group tell you when to stop. Have the others watch to see how quickly you are able to come to a complete stop. Next find a clear space that your teacher will allow you to run. Take off as fast as you can and again have someone in your group tell you when to stop and have the others observe. Discuss this quick investigation as a group to determine your results. Was it easier to stop quickly from a walk or a run? **Explain your reasoning.**

Now imagine vehicles on the roads, going slow and going fast. The important thing about traffic signs are that drivers are able to see and read them in time to follow them. Which of the reflective materials would allow drivers to read a sign sooner? In order to recommend one of these products you will need to use all of your prior investigative knowledge, as well as design an investigation to provide evidence that supports your recommendation with scientific proof.

Your group will act as test engineers on this activity. Test engineers design experiments they can test on products in order to assure they meet their requirements. You will be using the engineering design process to conduct your investigation. Rather than engineer a product, you will engineer a method of testing a product to verify its effectiveness to retroreflect.



EXPLORING the Science of RETROREFLECTIVITY

SAFE-D Texas A&M Transportation Institute

IDENTIFY the problem or challenge. What is the problem you are working to solve or question you are trying to answer?

As a group they are trying to design an investigation that will best determine the retroreflective material that will best be seen by drivers at night from the greatest distance allowing drivers to most safely follow traffic signs.

BRAINSTORM ways to solve the problem. What are some methods you could use to test the materials. Remember all ideas are worth writing down and considering!

Here there will be a variety of ideas. Remind them that this is for a fast moving vehicle at night. Some may even realize that they can cut out patterns in the same dark paper and place it over the retroreflective material for “drivers” to identify. If so, they will need the same pattern, so that the amount of light shone onto the pattern is equal for each sample, possibly turned in different directions for the “driver” to say at what point they can identify the shape and possbily the direction. Examples would be an arrow, a letter in the alphabet pointed in a different direction for each of the three samples. Depending on the hallway, you may encourage them to have dimmer light (flashlight) to shine as the samples are all very retroreflective, even a small sample of the each of the retroreflective samples is very bright.

DESIGN your investigation. After discussing your ideas, narrow your investigation down to the investigation that will give you answers that will best help you solve your problem. Describe your investigation design in detail.

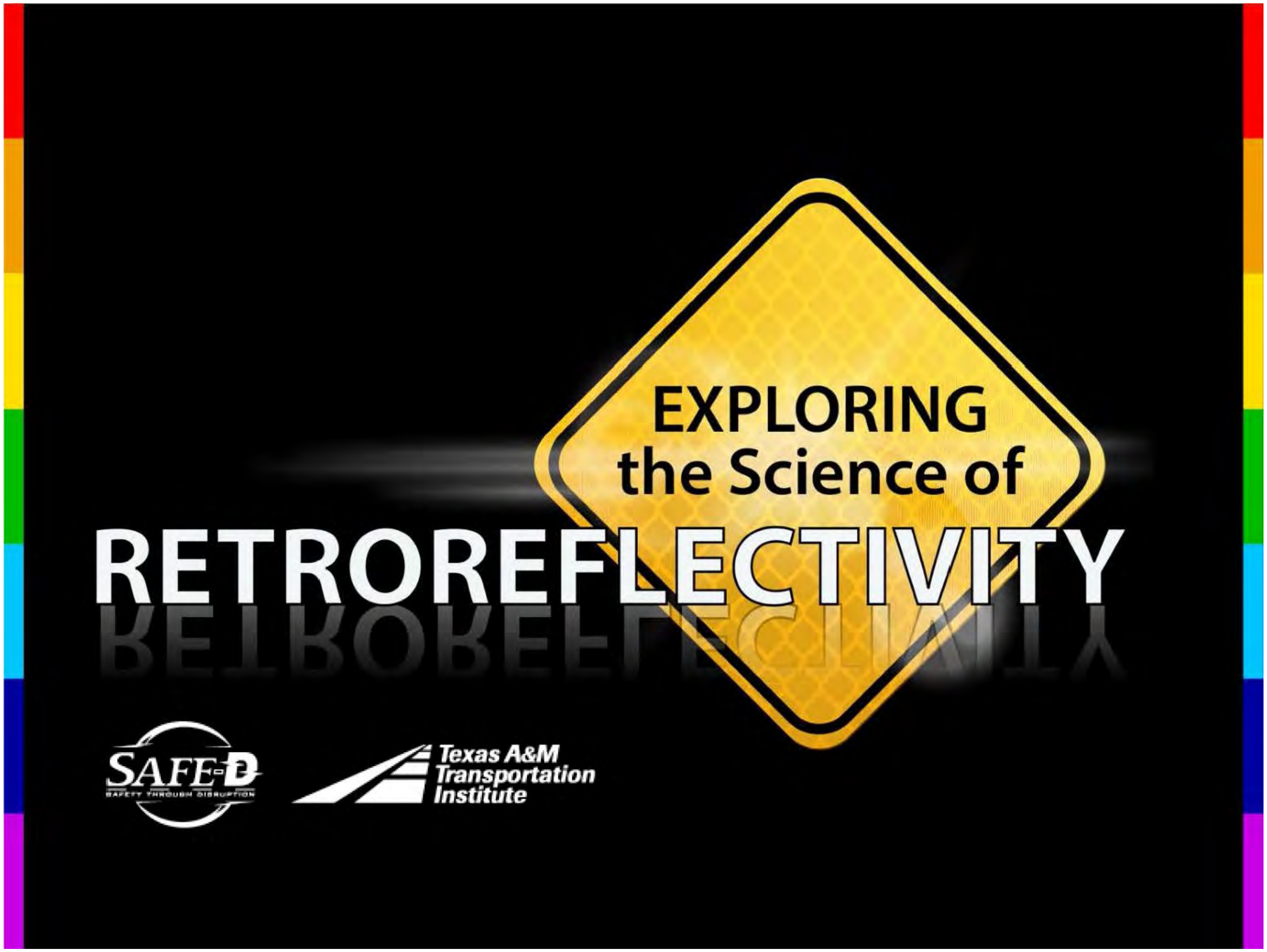
See above.

CREATE your investigation. Set everything up and prepare to investigate!

TEST AND EVALUATE! Conduct your investigation and record **ALL** observations, data, and more below. Draw any data charts, graphs and more you will be using to collect and analyze your data. Use a separate piece of paper as needed.

Appendix C – Presentation Slide Deck

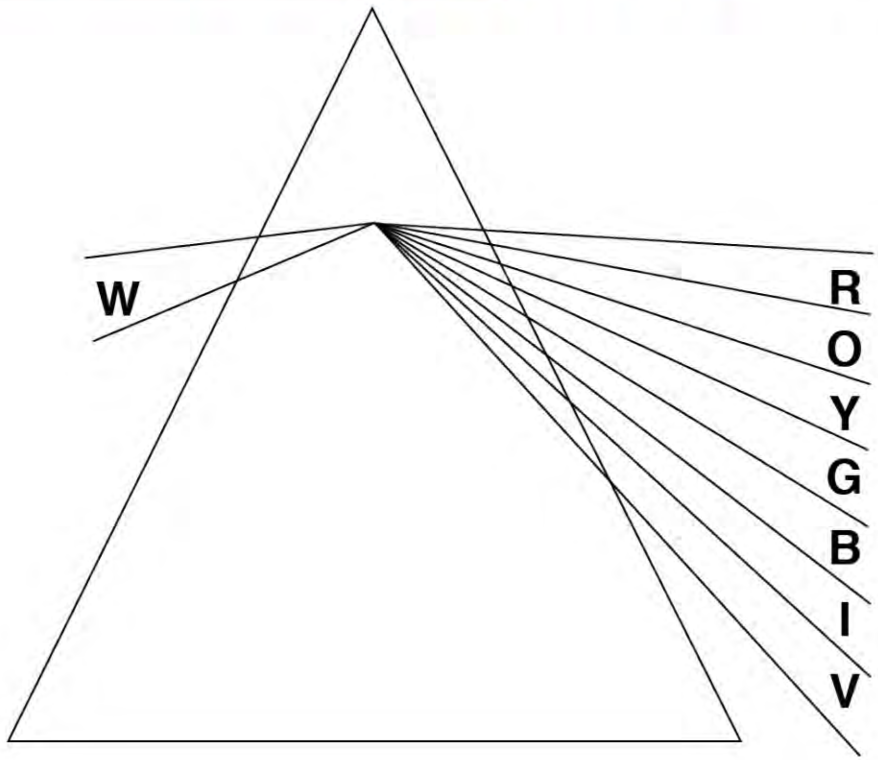
Appendix C contains the presentation slide deck. Slides are provided to aid teachers with demonstrations, student activities, and class discussion questions. The slide deck also contains fun facts in transportation. A PowerPoint slide file is available at https://tti.tamu.edu/safe-d.


EXPLORING
the Science of
RETROREFLECTIVITY
SAFE-D
Texas A&M
Transportation
Institute

EXPLORING the Science of RETROREFLECTIVITY

ENGAGE

TEACHER DEMONSTRATION: A RAINBOW OF LIGHT



STUDENT ACTIVITY: RAINBOW GLASSES

EACH OF YOU WILL BE GIVEN YOUR OWN RAINBOW GLASSES TO USE AND KEEP.

HERE ARE YOUR INSTRUCTIONS:

1) PUT ON GLASSES, WALK AROUND THE ROOM LOOKING AT VARIOUS LIGHTS, AND DESCRIBE TO YOUR TEAM WHAT YOU SEE.

2) PICK YOUR FAVORITE VIEW OF LIGHTS AND STOP TO ILLUSTRATE, COLOR, AND DESCRIBE WHAT YOU SEE ON YOUR LAB SHEET.

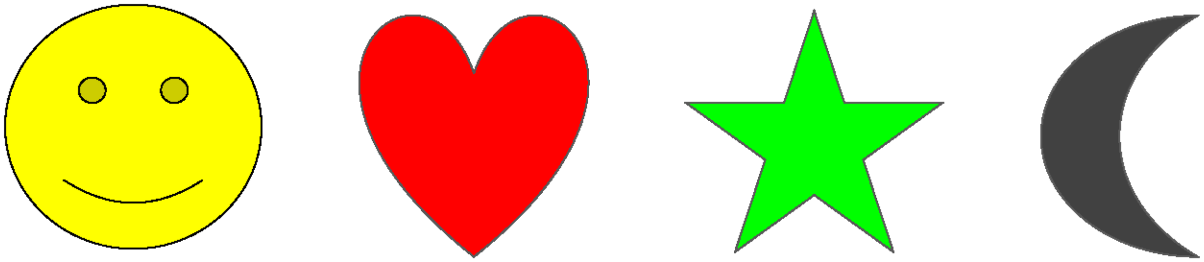
WHILE YOU MAY SEE SOME SUNLIGHT COMING INTO THE CLASSROOM:
DO NOT LOOK DIRECTLY AT THE SUN - EVEN WITH YOUR GLASSES ON!!

ENGAGE

CLASS DISCUSSION QUESTIONS

For each of the objects below, answer the following questions:

1. Which color, or colors, are reflected?
2. Which color, or colors, are absorbed?
3. How do you know?



FUN FACTS IN TRANSPORTATION

The first STOP sign was used in Detroit, Michigan in 1915.

The STOP sign evolved through many forms before coming to the white and red octagon we see everywhere today.

Early STOP signs had a yellow background with black letters. However, yellow was also the color used for warning signs and engineers wanted drivers to be able to quickly tell the difference between STOP and warning signs.

FUN FACTS IN TRANSPORTATION

Around the same time, red became the color used in traffic signals to indicate stop.

In order to unify traffic signals and STOP signs, a red background with white letters was chosen for STOP signs.

It was not until 1954 that the federal government worked to standardize sign shape and color across the country.

FUN FACTS IN TRANSPORTATION

What most stands out on these early signs?

Do you notice words or background colors first?

Why do you think you see them this way?


EXPLORING
the Science of
RETROREFLECTIVITY
EXPLORE

STUDENT ACTIVITY: ANGLE OF REFLECTION

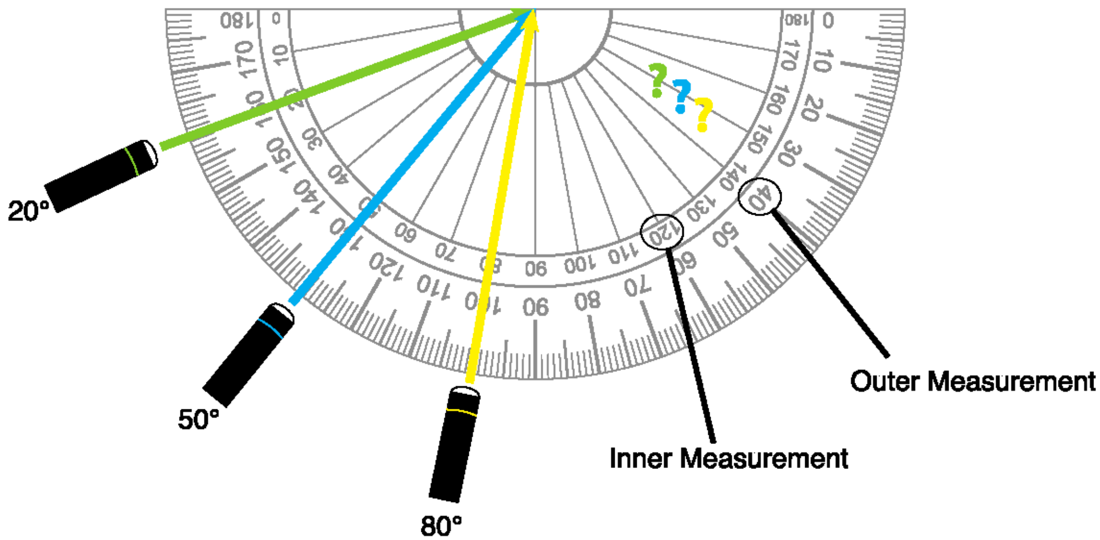
BEFORE WE START! SAFETY REMINDER!

DO NOT AIM YOUR LASER POINTER AT ANYONE.

ALWAYS HAVE A PATH THROUGH EACH MEDIUM AND A TARGET.

DO NOT LOOK DIRECTLY AT THE LASER POINTERS.

AIM FOR THE CENTER OF THE MIRROR



CLASS DISCUSSION QUESTIONS

We can see the sign ahead because it is daytime. In rural areas, signs are placed 12 feet to the right of the road.

At night, when a vehicle's headlights shine on a sign to the right of the road, according to the angle of reflection where should the light end up going?

Where does the light need to go for drivers to be able to see and read the sign at night? Why?

STUDENT ACTIVITY: DIFFUSION

BEFORE WE START! SAFETY REMINDER!

DO NOT AIM YOUR LASER POINTER AT ANYONE.

ALWAYS HAVE A PATH THROUGH EACH MEDIUM AND A TARGET.

DO NOT LOOK DIRECTLY AT THE LASER POINTERS.

Color everywhere you see the laser light in or around the plastic.

Draw arrows to show the various directions of travel.

CLASS DISCUSSION QUESTIONS

Why would you use your low beam (dim) headlights in fog rather than your high beam (bright) headlights?

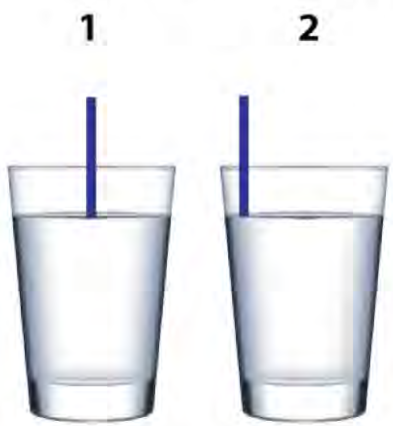
STUDENT ACTIVITY: REFRACTION

BEFORE WE START! SAFETY REMINDER!

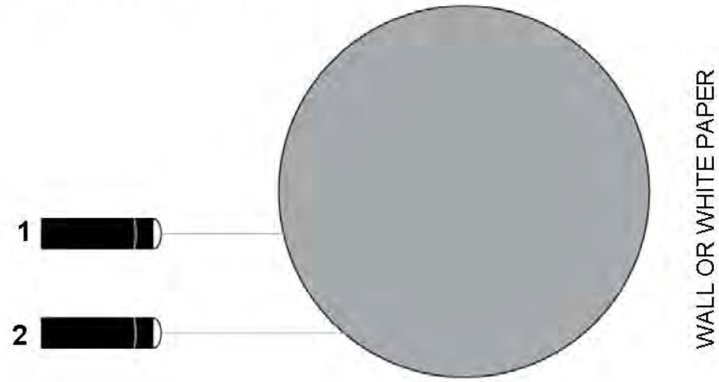
DO NOT AIM YOUR LASER POINTER AT ANYONE.

ALWAYS HAVE A PATH THROUGH EACH MEDIUM AND A TARGET.

DO NOT LOOK DIRECTLY AT THE LASER POINTERS.



COMPLETE THE STRAW'S IMAGE, FOR EACH GLASS, BELOW THE SURFACE OF THE WATER.



COMPLETE THE LASER'S IMAGE, FOR EACH POSITION, AS IT TRAVELS THROUGH THE WATER.

CLASS DISCUSSION QUESTION

In America, low beam headlights provide a distribution of light to illuminate the roadway in front of and to the right of the driver. Why?

Credit: Sapphire Technical Solutions

What about in countries where they drive on the other side of the road?

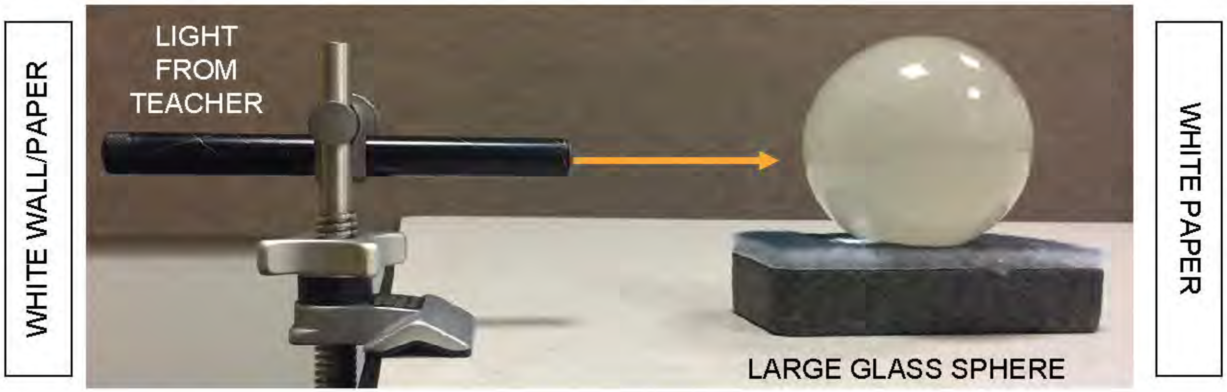
EXPLORING the Science of RETROREFLECTIVITY

EXPLAIN

EXPLAIN

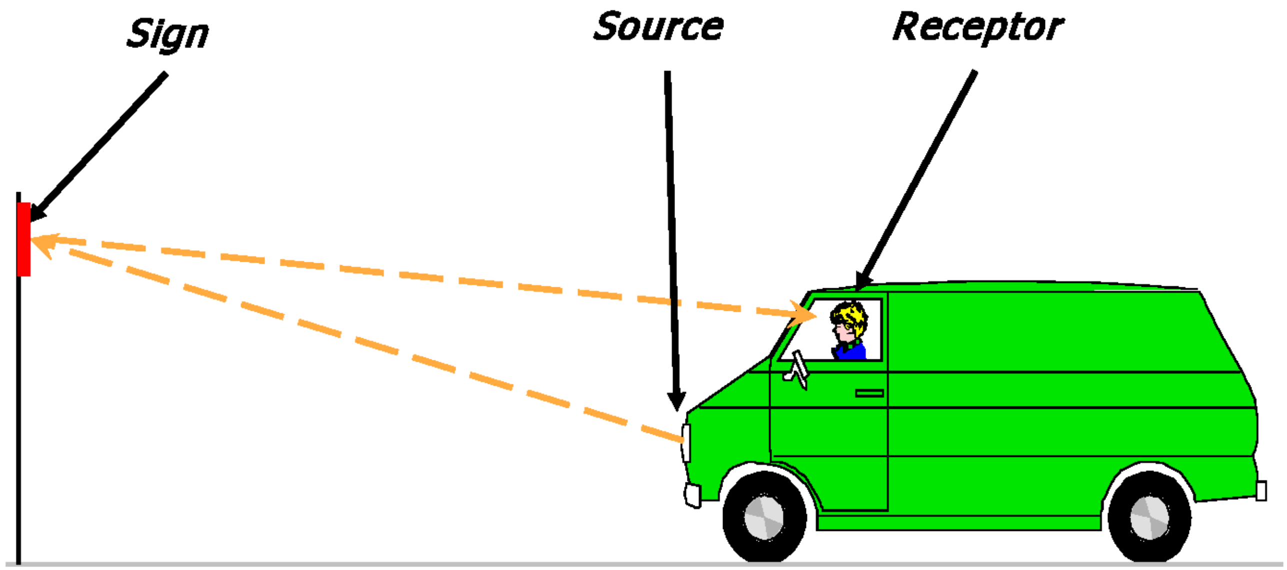
TEACHER DEMONSTRATION:
LIGHT THROUGH A GLASS SPHERE

Where does the light go? Draw arrows and color to illustrate what you see as the light from the flashlight and laser is transmitted through the glass sphere.



TEACHER DEMONSTRATION:

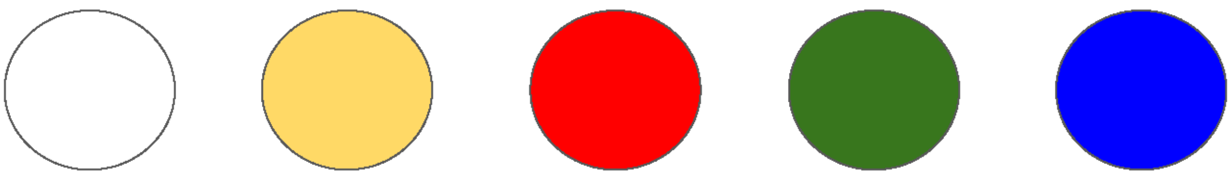
Retroreflection



STUDENT ACTIVITY: DOES COLOR MATTER?

Which colors retroreflect light the best?

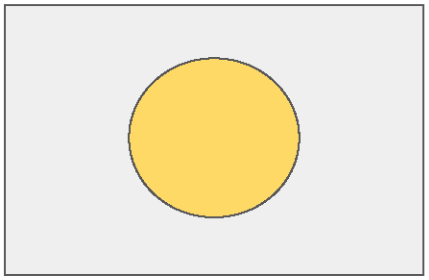
Choose a clear marble and four other marbles of your choice. Place them on a light colored or white background. Holding the flashlight on your chin, shine the light directly on each marble.

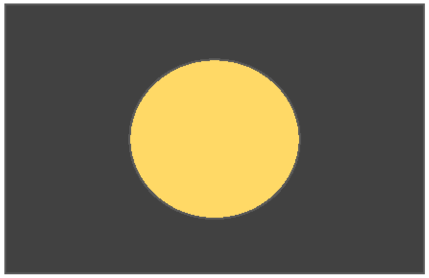


CLASS DISCUSSION QUESTION

Why did we place the marbles on a white or light colored surface?

What if we placed the marbles on a dark surface? Would it change how much light they reflect?





FUN FACTS IN TRANSPORTATION

Does color matter? It does when it comes to the markers along the road! See if you can guess what each color marker indicates!

WHITE
Separates traffic flow in the same direction

YELLOW
Separates traffic flow in the opposite direction

RED
Indicates you are going the wrong way

BLUE
Marks the location of fire hydrants

VIDEO RETROREFLECTIVITY

VIDEO: Retroreflective Materials: MAC RiAus PDplus

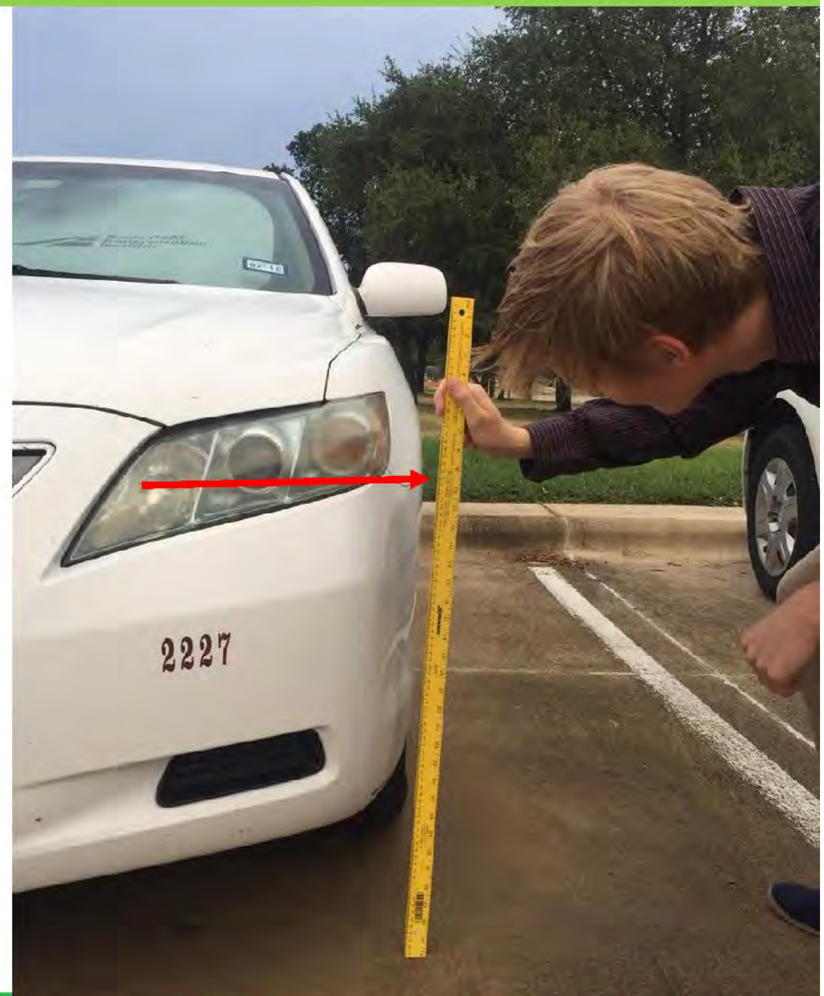
https://www.youtube.com/watch?v=rDRTmymuNyE

EXPLAIN

EXTENSION 1:

MEASURING HEADLIGHTS AND CALCULATING AVERAGES

Using a meterstick, gather data on 10 different vehicles from the teacher parking lot. Measure the height from the ground to the approximate center of the headlight. Be sure to measure in meters and centimeters.



CLASS DISCUSSION QUESTIONS

What makes a good sampling of vehicles? How do you know?

Why could it be beneficial to get some measurements from many different types of vehicles?

The average driver sits 1.1 m or 110 cm above the road.

Why is this an important number to know?

EXPLAIN

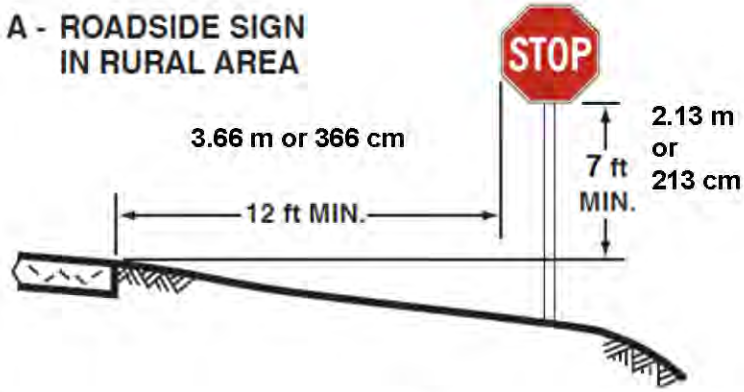
CLASS DISCUSSION QUESTIONS

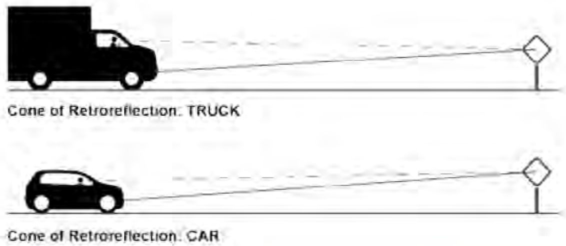
In rural areas, traffic signs are typically placed 7-ft high and 12-ft to right of the edge of the travel lane. Answer the following:

What role does retroreflection play for the driver to see this sign?

What properties of light do we see happening in the retroreflection?

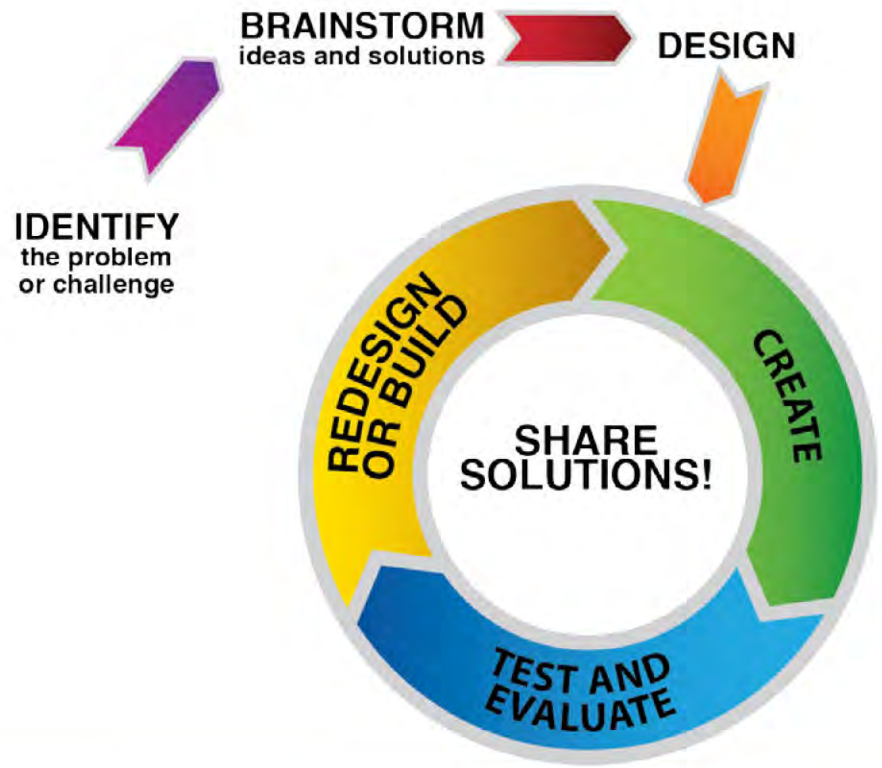
Which properties help retroreflection and which do not? Explain.






EXPLORING
the Science of
RETROREFLECTIVITY
ELABORATE

THE ENGINEERING DESIGN PROCESS



STUDENT ACTIVITY:

ENGINEERING DESIGN PROCESS CHALLENGE

DEFINE THE PROBLEM (Team):

What is it that you are trying to accomplish?

ONCE YOU HAVE DEFINED THE PROBLEM TOGETHER,
BREAK OFF AND WORK AS INDIVIDUALS ON THE NEXT TWO STEPS!

BRAINSTORM (Individual):

All ideas are a good idea at this stage. Here is where creativity is needed and no reasonable idea is wrong or bad.

STUDENT ACTIVITY:

ENGINEERING DESIGN PROCESS CHALLENGE

DESIGN (Individual):

Now it is time to work through all of the pros and cons of each of your ideas.

Here you will take into account the criteria, constraints and materials you have available. Keep in mind the objective, what you are specifically trying to accomplish. At this point you will put your design to paper with attention to each detail. Does it meet the proper criteria for success? Does it use only materials that are available?

STUDENT ACTIVITY:

ENGINEERING DESIGN PROCESS CHALLENGE

INDIVIDUALS SHARE IDEAS WITH THEIR TEAMS:

Now it is time to share each of your ideas with your team.

- Analyze the best ideas each team member's design demonstrates towards meeting your objective.
- Raise questions or concerns about models that may hinder accomplishing the objective or that are outside of the constraints.

ALWAYS BE POSITIVE AND RESPECTFUL WHEN ANALYZING OTHERS WORK!

STUDENT ACTIVITY:
ENGINEERING DESIGN PROCESS CHALLENGE

TEAM DESIGN:

Now it is time to put your individual ideas together to complete your team design!

While not everyone's ideas may be in the final design, each individual sign does help in the creative process and towards the team objective!

CREATE YOUR SIGN:

Make sure you list all the materials you use for this design and use ONLY materials from the list.

EXTENSION 2: BUILDING BETTER MODELS!

BUILDING A TEST CAR

Using recycled materials or items found around the classroom, create a car to test the retroreflectivity of each team sign.

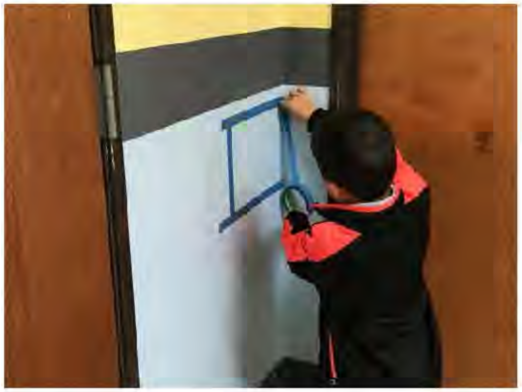
EXTENSION 2: BUILDING BETTER MODELS!

MATCHING THE SIGN TO THE TEST CAR

As a class, you will need to figure out where to hang your signs in order to test them with your car.

Remember our previous numbers: 7-foot (213 cm) high sign off to the right with our headlight average of _____ cm.

$$\frac{\text{Height of headlights on test car}}{\text{Height that you will hang the signs to test (X)}} = \frac{\text{Average height of headlights in parking lot}}{\text{213cm (7ft)}}$$



EXTENSION 2: BUILDING BETTER MODELS!

TESTING AT NIGHT– Modify your test area.

Since you will be testing your signs for a car driving at night, you will need to modify your test area.

STUDENT ACTIVITY:

ENGINEERING DESIGN PROCESS CHALLENGE

TEST AND EVALUATE DESIGN:

Test your sign to determine its retroreflectivity.

REDESIGN OR BUILD:

Based on the testing, think about ways to improve your sign.

SHARE SUCCESS:

Each team will present their team sign and ideas for improvement. As you watch others present, be sure to record the best features from their designs and concerns you may have.

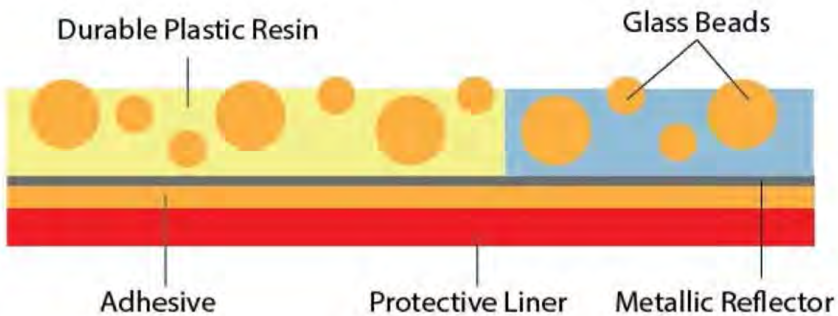
ELABORATE

FUN FACTS IN TRANSPORTATION

Glass spheres are among the most simple retroreflectors. With the right reflective surface behind or around them, they can bend and reflect light back to the source. As early as the 1920's important signs were improved by adding large glass spheres to make them more visible.

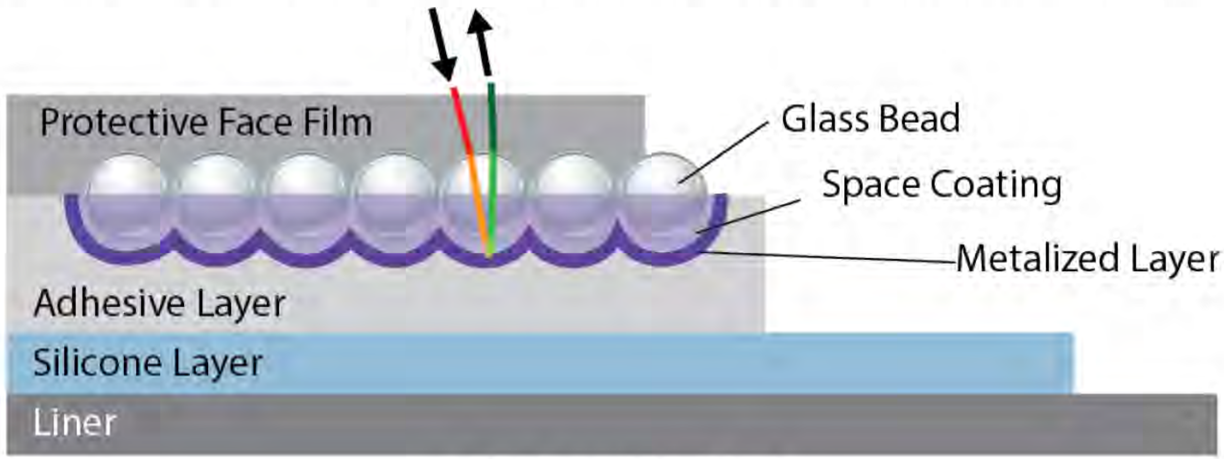
FUN FACTS IN TRANSPORTATION

Beginning in the 1940's, tiny glass retroreflecting beads were added to nearly all signs, and greatly improved traffic safety.



FUN FACTS IN TRANSPORTATION

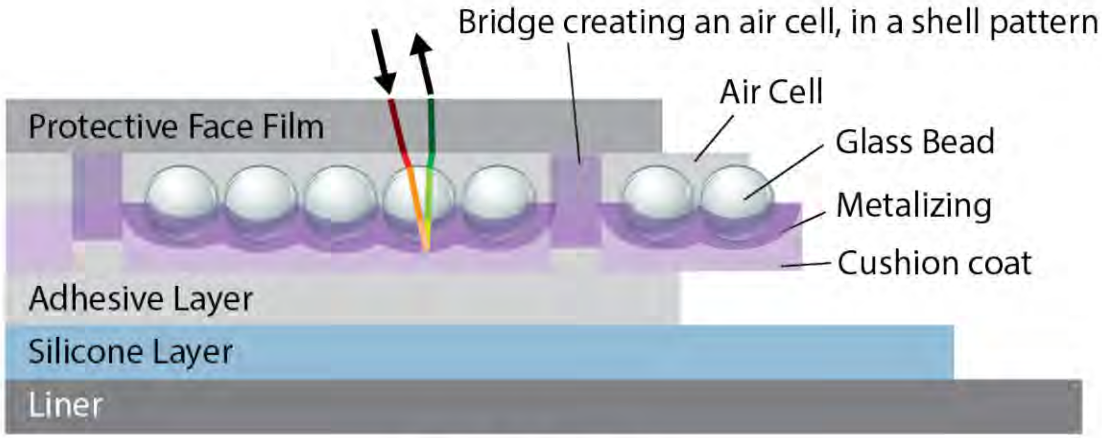
Soon after, a protective film was added over the glass beads to combat dust and water that distorted the retroreflectivity of the beads. In addition, the metallized layer was moved closer to the individual beads to improve retroreflectivity.



Engineering Grade

FUN FACTS IN TRANSPORTATION

In the 1970's, the metal coating was added to the back of each bead making them three to four times brighter.



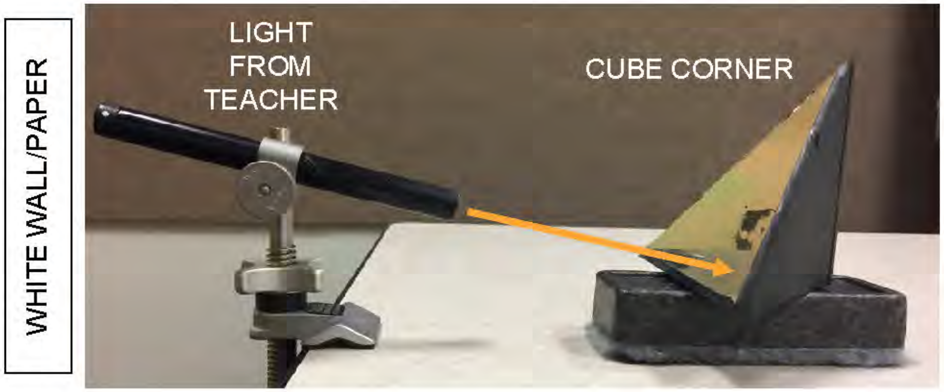
High Intensity

EXPLORING the Science of RETROREFLECTIVITY

EVALUATE

TEACHER DEMONSTRATION Prismatic Retroreflection

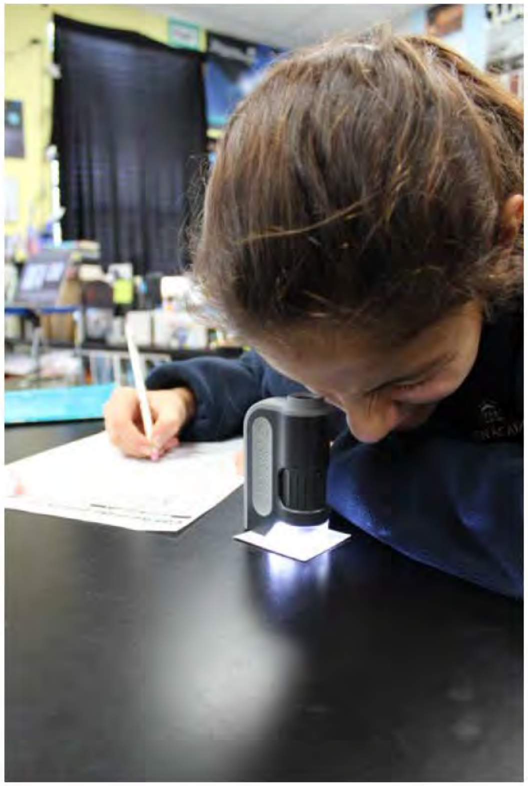
Some retroreflective materials contain thousands of cube corner retroreflectors in just a square inch of material.
This demonstration will help you understand how they work.



Video link for further demonstration and explanation: https://www.youtube.com/watch?v=S4vYq31cpyc

STUDENT ACTIVITY A CLOSER LOOK!

Now it is time for you to look at retroreflective sign sheeting up close!



STUDENT ACTIVITY: TEST ENGINEERING

You will now be a test engineer!

You will design your own method to test the retroreflectivity of each material (#1, #2 and #3).

You will analyze your findings and recommend the material with the best retroreflectivity for drivers at night!

Be sure that your investigation follows the engineering design process.

You will identify the problem or challenge.

Brainstorm ways to test retroreflectivity.

Create the test.

Conduct your investigation, analyze and share!

FUN FACTS IN TRANSPORTATION

"How the power of perseverance helped lead to a road safety breakthrough"

A Story about 3M Engineer, Tim Hoopman

"I have 37 patents. One in a thousand succeeds, so I must have 37,000 failures..."

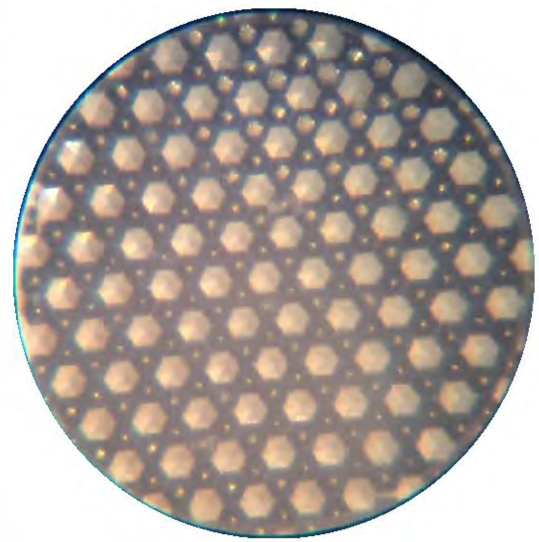
Tim Hoopman

VIDEO LINK

http://www.3m.com/3M/en_US/particles/all-articles/article-detail/~road-traffic-safety-reflective
-signs-visibility?storyid=2cb8314f-358f-4924-800e-cc2b75191237&wt.z_ch=fb&wt.z_cp=applied_to_life&wt.z_mt=photo&wt.mc_id=road+safety
2077

FUN FACTS IN TRANSPORTATION

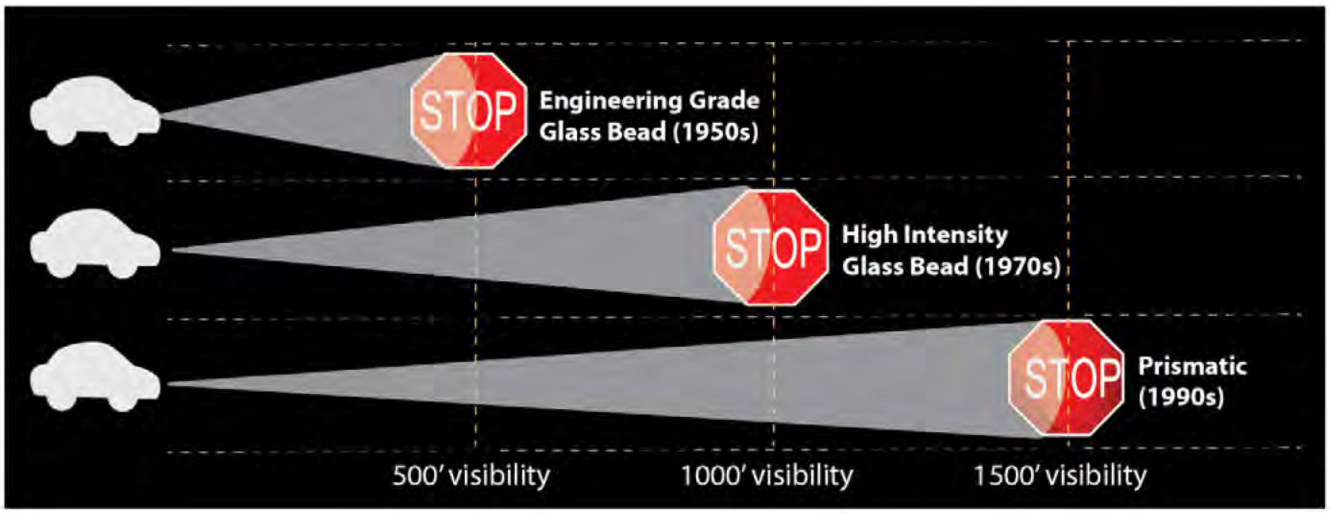
In the 1990s, microscopic prismatic sheeting became the latest solution to traffic safety with around 7,000 microprisms in every square inch.

Prismatic

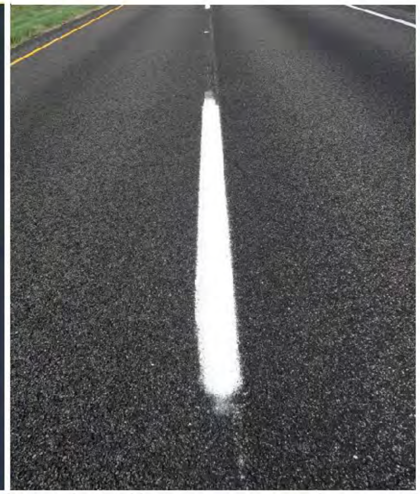
FUN FACTS IN TRANSPORTATION

This graphic shows the visibility improvements between Engineering grade, High Intensity, and Prismatic sign sheeting materials.



EVALUATE

FUN FACTS IN TRANSPORTATION



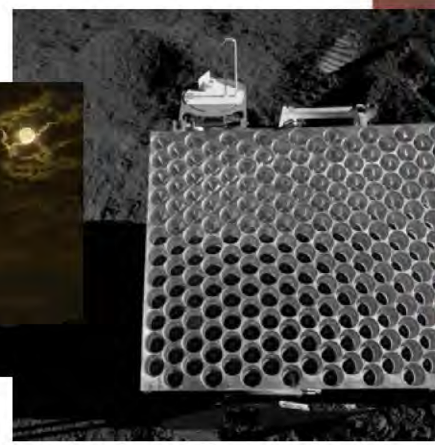
COOL FACT

MYTHBUSTERS: MOON HOAX RETROREFLECTORS!

Video Link: https://www.youtube.com/watch?v=VmVxSFnjYCA

McDonald Laser Ranging Station in West Texas, shines its laser light towards the moon's retroreflectors. Credit: McDonald Observatory.

Credit: NASA's Goddard Space Flight Center/Bill Hrybyk.



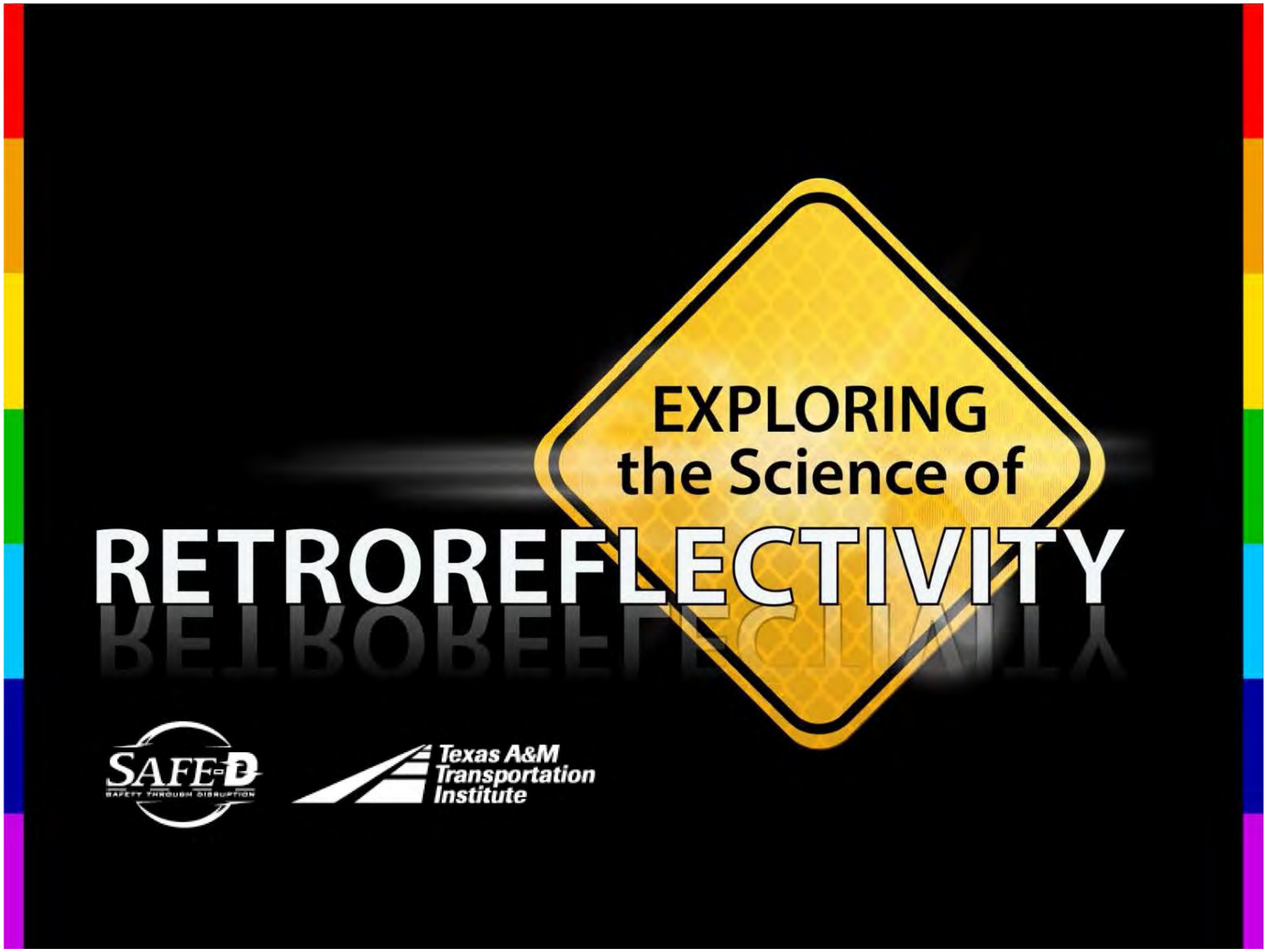
A portion of the Apollo 15 lunar laser ranging retroreflector array, as placed on the Moon and photographed by D. Scott.
Credit: NASA/D. Scott

Goddard Space Flight Center. Credit: NASA.

EXTENSION 3: RETROREFLECTIVE CLASS SIGN!

BUILD A RETROREFLECTIVE CLASS SIGN TO KEEP

Using materials found in the classroom and the consumable container in the TTI Retroreflection Kit, design and create a sign to hang up and keep in the classroom!


EXPLORING
the Science of
RETROREFLECTIVITY
SAFE-D
SAFETY THROUGH DISRUPTION
Texas A&M
Transportation
Institute