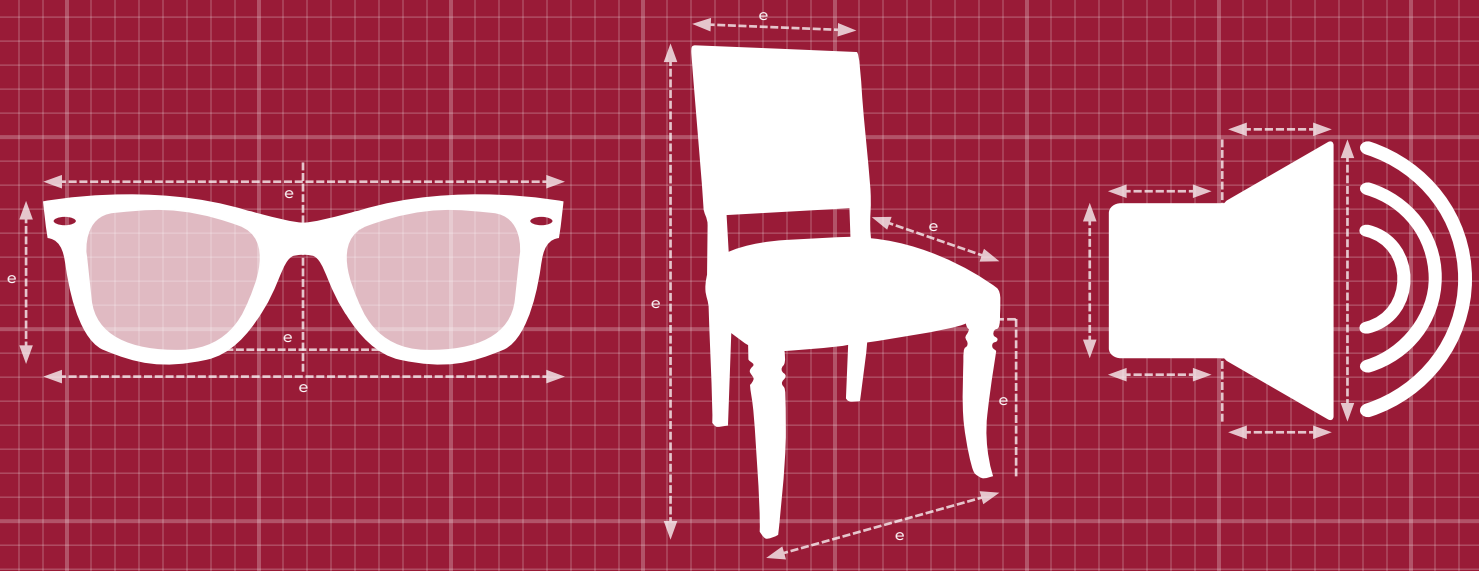
MORE EVERYDAY ENGINEERING

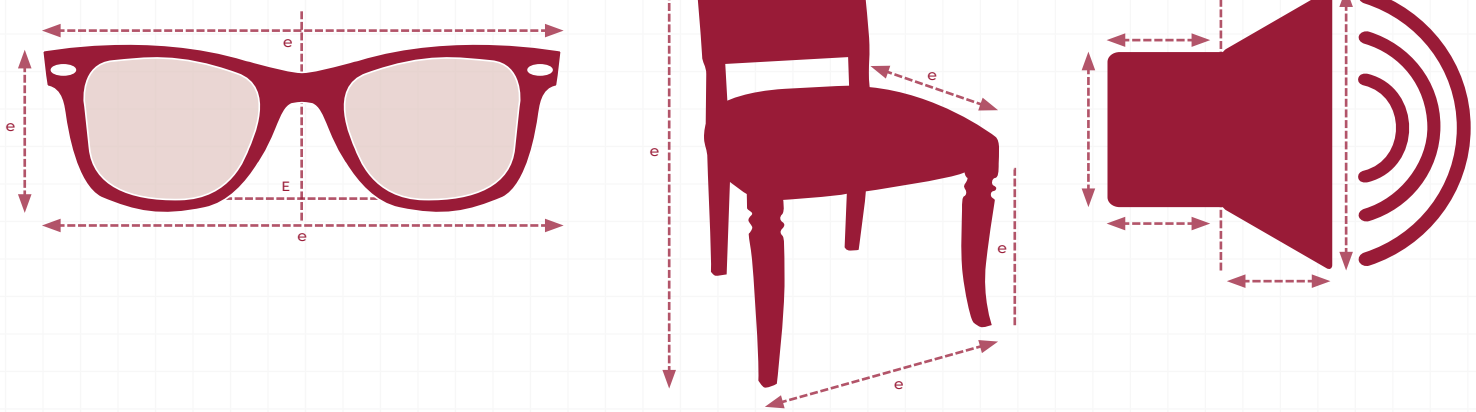


Putting the E in STEM Teaching and Learning

Richard H. Moyer and Susan A. Everett

NSTA press
National Science Teachers Association

MORE EVERYDAY ENGINEERING



Putting the E in STEM Teaching and Learning

MORE EVERYDAY ENGINEERING

Putting the E in STEM Teaching and Learning

Richard H. Moyer and Susan A. Everett

Photography by Robert L. Simpson III

NSTA press
National Science Teachers Association

Arlington, Virginia

NSTA press®
National Science Teachers Association

Claire Reinburg, Director
Wendy Rubin, Managing Editor
Rachel Ledbetter, Associate Editor
Donna Yudkin, Book Acquisitions Coordinator

Art and Design
Will Thomas Jr., Director

Printing and Production
Catherine Lorrain, Director

National Science Teachers Association
David L. Evans, Executive Director
David Beacom, Publisher

1840 Wilson Blvd., Arlington, VA 22201
www.*nsta.org/store*
For customer service inquiries, please call 800-277-5300.

19 18 17 16 4 3 2 1

Library of Congress Cataloging-in-Publication Data
Names: Moyer, Richard. | Everett, Susan A.
Title: More everyday engineering : putting the E in STEM teaching and learning / by Richard H. Moyer and Susan A. Everett ; photography by Robert L. Simpson III.
Other titles: Everyday engineering
Description: Arlington, VA : National Science Teachers Association, [2016] | Includes bibliographical references and index.
Identifiers: LCCN 2016026297 (print) | LCCN 2016027811 (ebook) | ISBN 9781681402789 (print) | ISBN 9781681402796 (e-book) | ISBN 9781681402796 (pdf)
Subjects: LCSH: Inventions--Popular works. | Engineering--Popular works.
Classification: LCC T47 .M726 2016 (print) | LCC T47 (ebook) | DDC 620--dc23 LC record available at *https://lccn.loc.gov/2016026297*

The Next Generation Science Standards ("NGSS") were developed by twenty six states, in collaboration with the National Research Council, the National Science Teachers Association and the American Association for the Advancement of Science in a process managed by Achieve, Inc. For more information go to *www.nextgenscience.org*

CONTENTS

ABOUT THE AUTHORS

RICHARD H. MOYER is emeritus professor of science education and natural sciences at the University of Michigan–Dearborn, where he developed and taught courses in the science education program. He is a co-author of McGraw-Hill's *Inspire Science* and *Science: A Closer Look*. He and Dr. Everett are co-authors of a college science methods book as well as the original *Everyday Engineering*. Dr. Moyer has conducted hundreds of teacher workshops both nationally and internationally.

SUSAN A. EVERETT is a professor of science education and chair of the Department of Education in the College of Education, Health, and Human Services at the University of Michigan–Dearborn. Dr. Everett, with Dr. Moyer, is the co-author of the featured column "Everyday Engineering" in the National Science Teachers Association's middle-level journal, *Science Scope*. Dr. Everett regularly teaches elementary science methods courses, graduate-level research courses, and inquiry-based Earth science classes.

ACKNOWLEDGMENTS

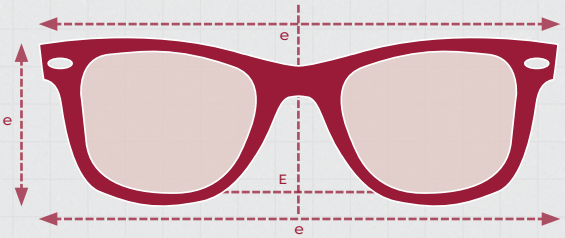
WE OWE A great deal to Inez Liftig, the longtime editor of *Science Scope*. Her knowledge and expertise in middle-level curriculum and learners are unsurpassed in our view. She helped us shape our ideas related to curriculum integration, recognizing differences among the teaching styles of our readers, and supported our attempts to make connections from the historical to the present day. Inez has a strong environmental education focus and many times shared ideas with us to further our thinking about how what we engineer has an effect on the Earth. She encouraged our attendance at yearly *Science Scope* advisory board meetings, which provided us with valuable feedback from the leaders in middle-level science education across the country. Through this experience we met Patty McGinnis, then a National Science Teachers Association (NSTA) middle-level director, who invited us to participate in the *Meet Me in the Middle* conferences within the NSTA conference where we shared engineering ideas with hundreds of middle-level science teachers. There is no doubt that without Inez's influence, *Everyday Engineering* and now *More Everyday Engineering* would be less than they are.

We would also like to recognize our colleagues and students at the University of Michigan–Dearborn. During several different semesters, in addition to methods class micro teaching, preservice students taught our lessons at STEM nights at various metropolitan Detroit schools as part of their clinical experiences. Our colleagues in the Inquiry Institute at the university were always quick to inquire about our most recent engineering project with a "What are you making?" or "What are you taking apart now?" In particular, we want to single out chemist and science educator Charlotte Otto, who was invaluable in helping us interpret some complex chemistry (plastic polymers among others) at an understandable middle-level manner. We have always been able to count on our photographer and illustrator, Robert Simpson III. He has a unique talent that allows him to capture the interesting "engineering parts" of our materials through his photographs. Without his photography, we would not be able to communicate our work to teachers; his photography truly is worth more than the proverbial thousand words.

Our editors at *Science Scope* certainly make us better writers as well. Led by Ken Roberts, both Kate Lu and Janna Palliser ask us important questions to ensure that we are really saying what we mean—so that our lessons will (hopefully) always be clear to our readers. Even when we do not, Kate and Janna tend to the details, providing clarity and accuracy for the teachers and students using the investigations. Finally, Claire Reinburg, director of NSTA Press, and Wendy Rubin, managing editor, have once again taken several years' worth of distinct *Science Scope* columns and magically put them together into this seamless volume, *More Everyday Engineering*.

—Richard H. Moyer and Susan A. Everett

CHAPTER 7



UV OR NOT UV? THAT IS A QUESTION FOR YOUR SUNGLASSES

HOW MANY PAIRS of sunglasses do you own? How do you decide which type to purchase? Choices range from dollar-store basics to high-end designer shades costing hundreds of dollars. Some people buy sunglasses for special purposes—for example, skiing, boating, or other outdoor recreational activities. Others own many pairs of inexpensive sunglasses to have some on hand at all times. You might also purchase prescription sunglasses. In addition, more and more people consider the health benefits of sunglasses, namely, how well they filter damaging ultraviolet (UV) light. According to the U.S. Environmental Protection Agency (2010, p. 1), "Long-term exposure to UV radiation can lead to cataracts, skin cancer around the eyelids, and other eye disorders."

In this 5E learning-cycle lesson, students use UV-sensitive beads to test different sunglasses' lenses to determine their ability to filter UV light. UV-sensitive beads are white but change color when exposed to UV light and return to white when the source of UV light is removed. In the *Next Generation Science Standards,* students should recognize that "[w]hen 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; NGSS Lead States 2013). This is essentially what sunglasses, like virtually all filters, do. Some of the light (including the UV portion) that strikes the lenses of sunglasses is reflected, some is absorbed (most of the UV portion), and the rest is transmitted through to the wearer's eyes. Sunglasses that are effective in protecting the eyes from UV light do so mostly by absorbing these harmful rays. UV radiation is that portion of the spectrum with wavelengths shorter than visible light. The longest wavelength of visible light (red) is 700 nanometers (nm), and the shortest is violet at 400 nm. Most of the UV radiation that reaches the Earth has wavelengths between 290 and 400 nm. This range includes what is referred to as UVA (320–400 nm) and UVB (290–320 nm) radiation. Most of the shorter wavelengths are filtered by the atmosphere and do not reach the Earth's surface (Skin Cancer Foundation 2016).

As students test different lenses, they will "[e]valuate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem" (MS-ETS1-2; NGSS Lead States 2013). In the United States, there are voluntary standards for sunglasses administrated by the American National Standards Institute (ANSI; ANSI 2015). The criteria in the ANSI standards require that sunglasses filter essentially 99% of the UV light below

wavelengths of 400 nm, allow colors to be perceived accurately, and be impact resistant.

Historical Information

As early as the 1200s, the Inuit of North America cut thin slits into walrus ivory to make a type of snow goggle to reduce the Sun's glare off of the snow and ice (Canadian Museum of History, n.d.). One of the earliest references to sunglasses appears in 1750, when Englishman James Ayscough noted that when glasses were "a little ting'd with Blue, it takes off the glaring Light from the Paper, and renders every Object so easy and pleasant" (Ayscough 1750, p. 13). Not until the 1920s, however, did sunglasses become popular with the general public. In 1929, Sam Foster sold inexpensive sunglasses on the boardwalk in Atlantic City, a popular tourist destination (Foster Grant 2013), and they quickly became a national fad (Life 1938). In the 1930s, Edwin Land (the same person who developed instant film cameras) invented sheets for polarizing light, an invention that was then used in sunglasses to reduce reflective glare (Rowland Institute at Harvard, n.d.). UV-protective sunglasses are a spin-off of NASA research at the Jet Propulsion Laboratory from the 1980s, where scientists studying birds of prey discovered that the birds produced an oil that protected their eyes from UV light. This research was first applied to the design of equipment for shielding welders' eyes and, ultimately, sunglasses (NASA 2011).

Investigating Sunglasses (Teacher Background Information)

Materials

Throughout this lesson, you will use UV beads—small plastic beads that have been treated so that they change color when exposed to UV light. In the absence of UV light, they are white in color but are available in numerous colors in the presence of UV light. We have used beads that change from white to purple. Similar beads are available at science supply companies for about $9 for 1,400 beads. After numerous cycles, they no longer completely return to white but remain milky gray. Be aware that there are also beads that glow different colors when exposed to UV light. For this activity, you want to be sure to obtain UV beads, not UV glow beads. Students will need to keep the beads away from UV light until they are ready for testing.

In the Engage phase, each student will need one bead, which will be sufficient for all of the other parts of the lesson. You may wish to start each class with fresh beads. In the Explore phase, each group of four students will need three different sunglass lenses. These can be obtained by taking apart old sunglasses or by purchasing them at a dollar store. One lens must not meet the ANSI standards noted earlier. You should be able to find these at dollar or party stores labeled as "fashion" or "novelty" glasses. The lenses can be reused from one class to the next. For students' lens tests, you will need to cut apart egg cartons. Each student group will need four individual egg holders; therefore, you will need one egg carton for every three groups of students—if you have five classes with six groups in each, you would need a total of 10 egg cartons. To tape the lenses to the egg holder, each group will need approximately 50 cm of duct tape. In addition to at least one pair of sunglasses, the same materials will be reused in the Extend phase of the lesson. Several small plastic bottles are needed for the Evaluate phase of the lesson. These can include prescription bottles, over-the-counter medication bottles, and small plastic vials.

Ideally, you need a bright window to test the various lenses. Most windows do not filter all of the Sun's UV light. Alternatively, you can take students outside. The activity will work on a cloudy day, but more time will be required for the beads to change color.

Engage

Begin this lesson by initiating a discussion of different ways people protect themselves from the Sun. We can classify damaging aspects of the Sun's radiation into three different categories: (1) People must protect themselves from the warmth of the infrared portion

of the Sun's spectrum so as to not become dehydrated or suffer heat stroke. (2) The visible part of sunlight is very bright and can damage the eyes if looked at directly. (3) Perhaps the most widespread concern for people is the UV radiation found in sunlight, which can lead to serious skin and eye damage.

Students will likely suggest wearing hats, sunscreen, and sunglasses, and, perhaps, limiting the amount of time spent in direct sunlight or keeping skin covered with long sleeves and long pants. This discussion may also reveal some common misconceptions students have, such as that getting a good tan can protect you from the Sun or that people of color cannot get skin cancer (Skin Cancer Foundation 2013).

To understand that the UV bead is an indicator of UV radiation, students should begin by placing their bead in a windowsill (see Figure 7.1), which emphasizes that the bead will cycle from white to colored and back to white in the presence or absence of UV light.

At this point in the lesson, students should be aware that sunlight contains UV radiation that is potentially harmful to humans. This lesson focuses specifically on learning how to test sunglasses to see if they are able to protect the eyes from this type of radiation.

FIGURE 7.1 UV beads change color on a sunny windowsill

Explore

Working in groups of four, students will test several different sunglass lenses. You may wish to have them design their own testing procedure or use the one provided in the student Activity Worksheet. While students are preparing their egg-carton testing apparatus (see Figures 7.2 and 7.3), they should keep the beads away from UV light, including classroom fluorescent

FIGURE 7.2 Bead taped to inside of egg holder

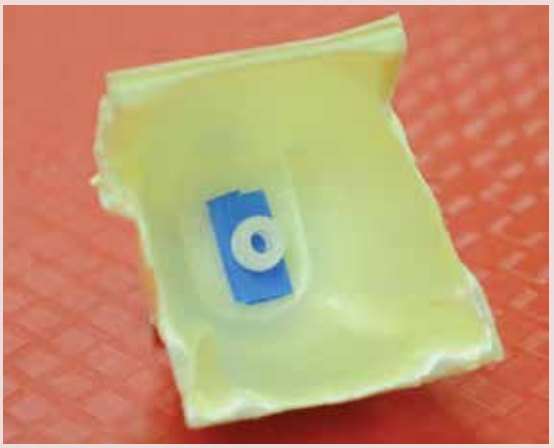
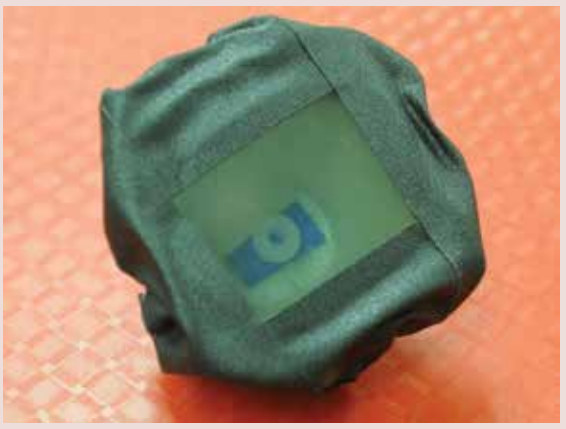


FIGURE 7.3 Bead in egg holder with sunglass lens



lighting, which may also cause a nominal tinting of the beads. The easiest way to do this may be to simply cover the beads with a sheet of paper or, once the bead is attached to the egg holder, turn it upside down on the table.

With a piece of folded tape, students will attach a bead to the bottom of one egg holder (as shown in Figure 7.2, p. 49) to prevent it from rolling into a corner where it may be in a shadow. A second bead is secured in the same manner in another egg holder and then the opening is covered with a lens from a pair of sunglasses. Students should seal around the lens with tape so that no light enters the second egg holder except through the lens (Figure 7.3, p. 49). Students will then point both egg holders directly toward the sunlight through a classroom window. On a bright, sunny day, students should see the uncovered bead change color in less than a minute. They should also deduce from this that the other bead has had enough time to change. If it has not, the lens must be filtering most of the UV light. Students will repeat this process for each lens. You should be able to conduct this testing on a cloudy day, although it will take longer for the beads to change color. Again, students can use the uncovered bead as a testing time indicator. *Safety note:* Warn students never to look directly at the Sun.

Explain

Students will find that most recently manufactured sunglasses work equally well at filtering UV light, as required by ANSI standards. Any glasses that do not meet these standards will allow some UV light to pass through the lens, resulting in the bead's color change. For a given amount of time, bead color variation to a darker shade indicates that more UV light has passed through the lens. Thus, the best lenses will allow virtually no change in the color of the bead and therefore provide the most eye protection.

Students may ask if polarized sunglasses protect the eyes from UV light. Polarized lenses are designed to cut glare that reflects off of horizontal surfaces rather than to filter UV light. However, many polarized sunglasses are also treated for the filtration of UV rays (EyeCare America 2007).

FIGURE 7.4 Child wearing wraparound sunglasses

Extend

Discuss with students how sunlight might enter their eyes even if they are wearing sunglasses, because, unlike in their testing, sunglasses are not taped to their faces. Students can demonstrate this design flaw by using a bead, egg holder, and lens that has not been sealed with tape. Students will observe that this bead changes color, indicating the presence of UV light.

The engineering challenge is to design a pair of sunglasses that will address these weaknesses and thus decrease the amount of UV light that enters the wearer's eyes (see Figures 7.4 and 7.5). All engineering designs have criteria to be addressed and constraints to be mitigated, which might lead to multiple solutions to a design challenge. For example, the child in Figure 7.4 is wearing a pair of wraparound sunglasses that block light from entering her eyes from the side. However, this design significantly limits her peripheral vision. Note how this constraint has been addressed by the

FIGURE 7.5 Assorted wraparound sunglasses

FIGURE 7.6 Small plastic bottles

design that includes a side lens in the adult glasses pictured in Figure 7.5.

Have students make sketches of their ideas, present their designs to the class, and explain how their designs provide additional protection.

Evaluate

As a performance assessment, students plan and conduct a test to determine if plastic medicine bottles filter UV light. If you gather used bottles (which come in a variety of colors), they should be thoroughly washed. You may also purchase this type of bottle from nearly any pharmacy. Students should now be able to design and conduct a similar test to the one previously described for sunglass lenses. Nearly all prescription bottles will filter UV light, so include additional small plastic vials as well (see Figure 7.6).

Conclusion

While there is much pressure for middle-level students to focus on fashion and design, ideally this engineering lesson will open their eyes to the importance of additional criteria when choosing sunglasses, including the filtration of UV light.

References

American National Standards Institute (ANSI). 2015. Ophthalmics—Nonprescription sunglass and fashion eyewear requirements (ANSI Z80.3-2015). *webstore.ansi.org/RecordDetail.aspx?sku=ANSI+Z80.3-2015*

Ayscough, J. 1750. *A short account of the nature and use of spectacles. In which is recommended, a kind of glass for spectacles, preferable to any hitherto made use of for that purpose. http://quod.lib.umich.edu/e/ecco/004798249.0001.000?rgn=main;view=fulltext*

Canadian Museum of History. n. d. Snow goggles. *http://collections.civilisations.ca/public/pages/cmccpublic/alt-emupublic/Display.php?irn=855927*

EyeCare America. 2007. Sunglasses. *www.aao.org/eyecare/tmp/sunglasses.cfm*

Foster Grant. 2013. About us: Origins of sunglasses. *www.fostergrant.co.uk/about.*

Life. 1938. Dark glasses are new fad for wear on city streets. *Life,* May 30. *http://books.google.com/books?id=3EoEAAAAMBAJ&lpg=PP1&pg=PA31#v=onepage&q&f=true*

National Aeronautics and Space Administration (NASA). 2011. Ultraviolet-blocking lenses protect, enhance vision. NASA Spinoff. *http://spinoff.nasa.gov/Spinoff2010/hm_3.html*

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states*. Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards*

Rowland Institute at Harvard. n.d. Edwin H. Land. *www2.rowland.harvard.edu/book/edwin-h-land*

Skin Cancer Foundation. 2013. The Skin Cancer Foundation busts myths surrounding Vitamin D and Sun exposure. *www.skincancer.org/media-and-press/press-release-2013/vitamin-d*

Skin Cancer Foundation. 2016. UVA & UVB. *www.skincancer.org/prevention/uva-and-uvb#*

U.S. Environmental Protection Agency. 2010. Prevent eye damage: Protect yourself from UV radiation. *www2.epa.gov/sites/production/files/documents/eyedamage.pdf*

Resource

Solar radiation and human health: Too much Sun is dangerous. WHO Information Fact Sheets. *www.who.int/uv/resources/fact/en/fs227toomuchsun.pdf*

ACTIVITY WORKSHEET 7.1

Investigating Sunglasses

Engage

1. What are some different ways that people protect themselves from the Sun? Share these ideas with your classmates.
2. Your teacher will provide you with a white plastic bead that is sensitive to certain types of light. Place your bead in a sunny window for about a minute, less if you notice a change in the bead's color. Record your observations.
3. Remove the bead from the window and hold it in your hand so that it is no longer exposed to any light for about two minutes. What happens to the bead after it has been removed from the sunlight near the window? Record your observations. These beads are sensitive to the ultraviolet (UV) light that is a part of sunlight. UV light, however, is invisible to your eyes. Therefore, the change in color of the beads indicates the presence of UV light.
4. UV light is harmful to your eyes. This is one of the reasons why people wear sunglasses. Are all sunglasses equally effective in protecting your eyes from this type of light? In this exploration, you will use the UV beads to test the lenses from different types of sunglasses.

Explore

1. You need to construct a testing apparatus so that the only light that reaches the UV bead must pass through the lens. You also need to make sure that the beads do not get exposed to UV light until you are ready to conduct a test. One method is to place a UV bead in one of the single egg holders from an egg carton. Fold over a piece of tape to secure the bead to the center of the egg holder. Cover the opening with the lens from one of the sunglasses you wish to test and then use duct tape to seal around the lens.
2. Tape a second UV bead into an egg holder without a lens attached and then hold each in a sunny window with both pointing directly at the Sun for one to two minutes. Do not look at the Sun directly while doing this part of the activity.
3. Return to your work area away from the bright window and quickly unseal the egg holder and compare the color of the two beads. Record your observations in a table like the one shown below and repeat for the other lenses. Be sure to start each test with a fresh white UV bead.

UV Bead Color Observations

Lens	Egg holder with no lens	Egg holder with lens
Lens # 1		
Lens # 2		
Lens # 3		

Explain

1. Which lens resulted in the darkest color change of the bead? The least?
2. Share your results with your classmates.
3. What does the amount of color change mean? Would a darker or lighter bead indicate a better lens to protect your eyes from UV light? Explain.
4. How do the lenses compare? Explain.

Extend

1. You know that UV light is harmful to your eyes and that some sunglasses are able to filter most

of the UV light that passes through them. How might UV light enter your eyes even if you are wearing sunglasses? Record your ideas.

2. Test a lens in the same way as above but without sealing it to the egg holder with tape. You will need to hold the lens in place while pointing it at the Sun. After one or two minutes, return to your work area and observe the UV bead and record your observations.
3. Compare these results with the testing done in the Explore stage, when you sealed the lens to the egg holder. Which test better represents how people actually wear sunglasses?
4. Your engineering challenge is to design a pair of sunglasses that will decrease the amount of UV light entering the wearer's eyes.
5. Examine the glasses your teacher provided to determine their design weaknesses that allow UV light to enter the wearer's eyes. Brainstorm ways the sunglasses could be modified to address these design weaknesses. Make a sketch of your improved sunglasses, labeling your changes. Explain how your design better protects the eyes from UV light. Present your design to your classmates.

Evaluate

There are many other things besides your eyes that can be damaged by exposure to UV light. One example is medication that is often sold in small plastic bottles. Design a procedure to test if different types of small bottles filter UV light. After your teacher has approved your plan, carry out your testing. Record your results and explain your findings.

INDEX

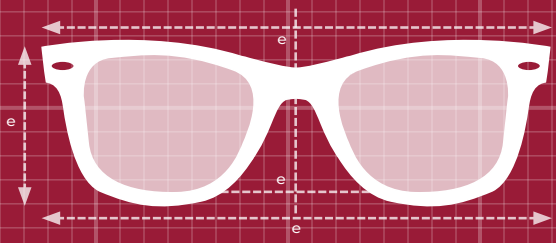
Page numbers printed in **boldface** type refer to figures or tables.

INDEX

INDEX

MORE EVERYDAY ENGINEERING

Putting the E in STEM Teaching and Learning



"In the conclusion to *Everyday Engineering*, we noted that we hoped we inspired you to look at your garlic press in a different way than you had before. We still have that wish. Be curious about the things you come across daily—a stapler, a doorknob, or a pepper mill. How do they work? How were they made? How could you improve on their designs? We also hope *More Everyday Engineering* helps you pass this innovative spirit along to your students so they recognize and appreciate that engineering is truly everyday."
—From Chapter 1 of *More Everyday Engineering*

This book is an ideal resource for sparking students' interest in the marvels of engineering behind seemingly simple items and events. Like *Everyday Engineering*, this new volume is based on the popular "Everyday Engineering" column in NSTA's award-winning middle school journal, *Science Scope*. Thirteen activities focus on three aspects of engineering: designing and building, reverse engineering to learn how something works, and constructing and testing models. Students can perform hands-on investigations of objects and phenomena they see all the time, asking questions such as these:

- What makes a windup toy get up and go?
- How does an earbud operate?
- Why does the line you're waiting in always seem the slowest?

Each activity includes a clear explanation of the science and history behind the object's or phenomenon's development, plus a materials list, student data sheets, and safety suggestions. The collection is useful for classroom teachers, as well as engineers leading outreach activities, leaders of after-school and summer enrichment programs, and parents. *More Everyday Engineering* will have your students taking a number of things apart while they develop a lifelong interest in engineering.

Grades 6–8

NSTA press
National Science Teachers Association

PB306X2
ISBN: 978-1-68140-278-9