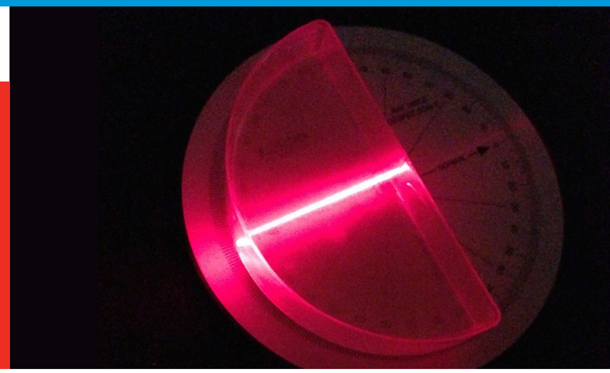
Nanotechnology—Using Refraction To Make Things Invisible



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ACTIVITY: NANOTECHNOLOGY—USING REFRACTION TO MAKE THINGS INVISIBLE

Big Idea

Nanotechnology is being used to create promising new metamaterials that bend or refract light and sound waves in ways not found in nature. There are many potential applications for these materials, one of which is to create "invisibility fields" for individuals or machinery.

Guiding Question

How and why does light refract and how can that be used on a nano level to create invisibility?

TIP: Be sure to practice the laser challenge before your classroom visit.

Materials

1. Refraction dish (1-2 per group)
2. Laser pointer (1 per group)
3. Protractor (2 per group)
4. Coffee creamer (1 pinch per group)
5. Paper (1 per group)
6. Pencil (1 per group)
7. Computer and Projector to show a short video and an image

Set Up

Arrange the desks so students can alternate between small-group work and all-class discussions and demonstrations.

Introduction

Teacher introduces the engineer/classroom visitor.

Setting the Stage

- Show the introductory video.
- Tell them who you are, what you do, and what it's like to work in your career.
- Tell them a story about how you got interested in engineering/your career or something that happened in your work that was really exciting—something that truly made a difference in your life.
- Show the activity PowerPoint presentation, as appropriate.

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Hands-on Activity

Introduce the use of nanotechnology to make items invisible

Ask students to think about their clothing. Ask: *What are some properties your clothing has? What are some functions your clothing performs?* (Keeps them warm, repels rain, doesn't wrinkle, etc.) Ask: *What are some examples of clothing made for a specific job or purpose? What properties make those clothes particularly useful for that job or purpose?* (Firefighters' suits are flame resistant, military uniforms are camouflaged, soccer players' jerseys are light and dry quickly, etc.) Ask: *What are some examples of special clothing have you read about or seen in movies that you wouldn't see in real life? What special properties and functions does that clothing have?* (Harry Potter's invisibility cloak, Hermes' winged shoes, Iron Man's armor, dragon-scale armor, etc.) Explain that at least one of these ideas from fiction may soon be available in real life. Ask students to guess which one.

Explain that researchers are currently exploring ways to use nanotechnology to make clothing that will make the wearer appear invisible. Nanotechnology is a way to change the properties of matter by precisely moving and placing atoms and groups of atoms. This rearrangement can result in metamaterials, which are artificial materials with properties not found in nature. One metamaterial in development could act as a kind of invisibility cloak. This metamaterial works by bending or refracting light in a way that light is not normally refracted in nature. By bending the light around the wearer in this way, the metamaterial would make anyone wearing it effectively invisible. Scientists have done this with one kind of wave—microwaves. They are now working on doing the same thing with visible light.

Investigate refraction

Explain to students that while you can't manipulate light on a nano level in the classroom, you can see how light bends or refracts in the natural world. Divide students into five small groups and give each group two protractors, a laser pointer, and a refraction dish. Remind students that they should be very careful not to shine the laser pointer in anyone's eyes. Have one person from each group fill the refraction dish $\frac{2}{3}$ full of water, add a small pinch of coffee creamer, and stir gently. Have each group take out three pieces of paper and a pen or pencil.

Use the images provided as a guide for setting up the materials for this activity. Have students place the protractors on the table with their straight ends touching so that the two protractors form a circle. Have them fold one piece of paper in half (long way) and then in half again so they end up with a piece of paper about $\frac{1}{4}$ as wide as usual. They should lay this piece of paper across the two protractors so that one edge lines up with the 60° mark on both protractors. Then have students place the refraction dish so that the straight edge of the refraction dish lines up with the hole in the protractor farthest from them. The refraction dish should be centered within the arc of the protractor. When students have finished the setup, the refraction dish should be oriented so that the straight edge is facing students and the second protractor is between students and the straight edge of the dish.

Next, have students shine the laser pointer along the edge of the paper so that it enters the refraction dish at a 60° angle. Have students observe the laser beam as it travels through the water and out the other side. Ask: *Does the beam follow the straight line indicated by the paper? How would you describe what the beam does when it enters the water?* Have students read the protractor on the side where the beam exits the refraction dish. Ask: *Is there a difference between the angle the beam would have been at had it traveled straight through the water and the angle at which it actually exited? What is that difference?* Introduce the vocabulary terms *normal line, angle of incidence,* and *angle of refraction.* Have students find each of these.

Invite students to experiment with shining the laser beam into the refraction dish at different angles, noting the angle of refraction. Encourage students to write down their observations, as they might be helpful during the challenge you will give them. Challenge them to identify a pattern or trend in what they are observing. How does the angle of incidence relate to the angle of refraction? Give students five minutes to experiment and make observations.

Take the refraction challenge

Challenge students to apply what they learned from observing how the angle of incidence relates to the angle of refraction. Have them place a line on a piece of paper, low enough so that it can be seen through the refraction dish and perpendicular to the table. Explain that this line is their target. Have one student in each group hold the target anywhere along the curved side of the refraction dish but about 6 inches away. Challenge students to line up the laser pointer so that it will hit the target when turned on. Tell students the challenge is to hit the target in as few tries as

possible. Remind them to use what they learned in their investigation to inform their choices. Give students about five minutes to try the challenge. Once they have succeeded, they can move the target and try again.

After students have been able to hit the target two or three times, challenge them to team up with another group and try to hit a target through both teams' refraction dishes. They should line the dishes up so that the straight edge of one dish touches the curved edge of the other dish, as shown in the images provided. If there is time, the class can work together to hit a target through three, four, or all five refraction dishes.

Wrap-Up

Discuss the experiment and challenge with students

Ask: *How would you describe refraction? What pattern or trend did you see in how the angle of incidence is related to the angle of refraction? How did you use this information to meet the challenge? Did you find the challenge easy or difficult? Why?*

Ask students if they know of anything in the natural world that is invisible. If necessary, distinguish invisible from simply camouflaged, like a chameleon. Explain that there is no invisibility in the real world, because there is no material in nature that bends light in the right way to make something invisible. Reiterate that it is only through the specific manipulation of atoms using nanotechnology that such a metamaterial can exist.

Ask students to imagine they are engineers designing a new material for clothing. What properties would they design the material to have and why?

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SUPPORT MATERIALS—FOR THE CLASSROOM VISITOR

Background Information

Nanotechnology is a way to change the properties of matter by precisely moving and placing atoms and groups of atoms. This rearrangement can result in metamaterials with properties not found in nature. Some examples currently on the market include fabric that won't wrinkle or stain and water-resistant substances. One metamaterial in development could act as a kind of invisibility cloak. This metamaterial works by bending or refracting light in a way that light is not normally refracted in nature. By bending the light around the wearer in this way, the metamaterial would make anyone wearing it effectively invisible. This type of invisibility cloak is still a long way from market. Scientists have proven the concept using microwaves on a micro level. The challenges they now face are how to make this work with visible light and how to make it work on a large-enough scale to actually hide visible objects.

The metamaterials being investigated for use in invisibility have unique refractive properties not normally found in nature. Refraction is the bending of a light wave as it passes from one medium, such as air, to another medium, such as water. This bending occurs because of a change in the speed of light as it travels through these different mediums. In order to bend light around a material, that material would need to have a negative refractive index. The refractive index describes how much light bends as it passes from one substance to another. In nature, the refractive index is always positive. Think of the common demonstration of refraction when a pencil is placed in a clear glass of water and appears bent. If the water had a negative refractive index, the pencil would appear to bend back on itself. The manipulation of atoms using nanotechnology makes it possible to create a metamaterial that has a negative index of refraction.

National Standards Alignment

- (5–8) Standard A-1: Abilities necessary to do scientific inquiry
- (5–8) Standard B-3: Transfer of energy
- (5–8) Standard E-1: Abilities of technological design

Next Generation Science Standards Alignment

- CCC: Engineers improve existing technologies or develop new ones to increase the technologies' benefits, decrease known risks, and meet societal demands (3-5-ETS-2)
- DCI: PS4.B: Electromagnetic Radiation: The path that light travels can be traced as a straight line except at surfaces between different transparent materials where the light path bends. (MS-PS4-2)

Preparation For Your Classroom Visit

Once a classroom visit has been established, check in with the host educator to make sure students are prepared and have some prior knowledge about the topic you have selected to share with the class.

An educator guide has been created for you to share with the host educator before your classroom visit. This guide includes pre- and post-visit resources and suggested activities that support the content you will be presenting during your classroom visit. Some of the information in the educator guide has been provided in the "Support Materials—For the Educator" section at the end of this document. Share the educator guide for this activity with the classroom educator as soon as you have a date for your visit. The educator guide can be found in the educator version of the Engineers in the Classroom website (www.classroomengineers.org).

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Prior Knowledge

Students should be somewhat familiar with light refraction and reflection.

Familiarize yourself and the educator with the following terminology:
angle of incidence, angle of refraction, metamaterial, nanotechnology, normal line, refraction

Other Resources to Explore

- Article: CNN Tech—Scientist come a step closer to 'invisibility cloak'
  http://www.cnn.com/2013/03/27/tech/invisibility-cloak/
- Article: National Geographic—Smart Shirts
  http://education.nationalgeographic.com/education/news/smart-shirts/?ar_a=1
- Encyclopedic Entry: National Geographic—Nanotechnology
  http://education.nationalgeographic.com/education/encyclopedia/nanotechnology/?ar_a=1
- Video: National Geographic—Nano's Big Future
  http://ngm.nationalgeographic.com/2006/06/nanotechnology/kahn-text
- Video: How Stuff Works—Sci Fi Science: Invisibility Cloak
  http://science.howstuffworks.com/40116-sci-fi-science-invisibility-cloak-video.htm
- Video: National Geographic: Mysteries of the Unseen World—Nano World: Try These Particles on for Size
  http://education.nationalgeographic.com/education/media/nano-world/?ar_a=1
- Video: National Geographic: Mysteries of the Unseen World—Nano Science: A New Frontier
  http://education.nationalgeographic.com/education/media/nanoscience/?ar_a=1
- Video: Nanoscience Informal Science Education Net—Intro to Nano
  https://vimeo.com/channels/nisenet/11362918
- Website: National Geographic—Mysteries of the Unseen World
  http://education.nationalgeographic.com/education/mysteries-unseen-world/?ar_a=1
- Website: National Nanotechnology Initiative—Nanotechnology 101
  http://www.nano.gov/nanotech-101/what
- Website: Nano.gov: Nanotechnology—Big Things from a Tiny World
  http://www.nano.gov/sites/default/files/pub_resource/nanotechnology_bigthingsfromatinyworld-print.pdf
- Website: Nanoscale Informal Science Education Network—K-12 Resources
  http://www.nisenet.org/community/k-12-teachers
- Website: Lockheed Martin—Nanotechnology
  http://www.lockheedmartin.com/us/what-we-do/emerging/nanotechnology.html

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Classroom Management Tips

1. Consult the teacher prior to the class period so your classroom management approach aligns with the management plan, routines, and procedures the teacher already has in place. When relevant, discuss learning needs or behavioral challenges of specific students.
2. Establishing a culture of mutual respect and trust is key. At the beginning of the class period, tell students about yourself and why you are there. Discuss a clear and concise set of rules/expectations that are phrased positively.
3. Complete any necessary setup prior to the start of the class period. Be well-prepared and organized so you can keep things moving. "Down time" can lead to a loss of student attention.
4. Help yourself stay on track with the activity and its objectives by using a timing device and notecard to guide you. The notecard could include a brief outline of the activity, key concepts/vocabulary, and questions to facilitate discussion. Use a timing device to stay on schedule. You could even enlist the help of one or more students to be your "timekeepers."
5. If you do lose students' attention, use existing strategies the teacher has in place to "bring them back" to the task at hand. Examples include interactive clapping, counting, hand-raising, and other forms of nonverbal communication.
6. Moving around the classroom, varying the tone and volume of your voice, enlisting volunteers to assist you, and calling on students to answer questions and share their ideas can help keep students engaged and focused. Avoid lecturing and talking at students without any interaction, especially for more than a few minutes at a time.
7. Avoid open-ended questions that encourage students to share their own experiences in a story-like manner. This can use up valuable time and distract students from the task at hand.
8. Seek teacher assistance in grouping students. Groups could be pre-determined based on specific criteria, i.e. student learning and communication styles, ability to self-direct, and collaboration skills. During group work be sure to circulate around the room, engage students with questions, and use proximity control to keep students on track.
9. Be yourself and have fun! If you are enjoying yourself and engaging with the students and the activity, then they will do the same.

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SUPPORT MATERIALS—FOR THE EDUCATOR

Pre-Visit Resources And Activities

- Use the National Geographic Mysteries of the Unseen World collection (http://education.nationalgeographic.com/education/mysteries-unseen-world/?ar_a=1) to engage students and provide some context and relevant background information:
  - Video: National Geographic: Nanoscience—A New Frontier
    http://education.nationalgeographic.com/education/media/nanoscience/?ar_a=1
  - Video: National Geographic: Nano World—Try These Particles on for Size
    http://education.nationalgeographic.com/education/media/nano-world/?ar_a=1
  - Activity: National Geographic: Properties of Matter—Macro to Nano Scale
    http://education.nationalgeographic.com/education/activity/properties-matter-macro-nano-scale/?ar_a=1
  - Article: National Geographic—Smart Shirts
    http://education.nationalgeographic.com/education/news/smart-shirts/?ar_a=1
- Pre-teach relevant vocabulary: angle of incidence, angle of refraction, metamaterial, nanotechnology, normal line, refraction

Post-Visit Resources And Activities

- Review relevant vocabulary/concepts: angle of incidence, angle of refraction, metamaterial, nanotechnology, normal line, refraction
- Possible extensions:
  - Students research and propose additional applications for nanotechnology-based metamaterials.
  - Activity: National Geographic—Nano World Revealed
    http://education.nationalgeographic.com/education/activity/nano-world-revealed/?ar_a=1

For Further Exploration

- Extension Activities: Science Enhancement Program—Materials by Design
  http://www.nationalstemcentre.org.uk/elibrary/collection/572/sep-materials-by-design
- Extension Activity—Try Engineering: Lesson Plans (use keyword “materials”)
  http://www.tryengineering.org/lesson-plans