SOCIETY OF PHYSICS STUDENTS SOCK

Science Outreach Catalyst Kit

2014-15 LIGHT: A SPECTRUM OF UTILITY

A set of hand-on experiments and activities addressing the following questions:

- How do we use light every day?
- How can light tell us about matter and its structure, and why does structure matter?

This manual was produced as part of the SPS Internship Program. For more information about the unique experience of being an SPS Summer Intern, see

http://www.spsnational.org/programs/internships/.

More information about the SPS SOCK program, including electronic versions of the manuals from past SOCKs:

http://www.spsnational.org/programs/socks/index.htm.

For more information about the Society of Physics Students, see

www.spsnational.org

or email us at sps@aip.org or sps-programs@aip.org.

By the 2014 SPS SOCK Interns
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Dear SOCK recipient,

We would like to congratulate you on your interest in science outreach! It is an excellent way to promote the sciences in your community and solidify your understanding of the physics in question. The title of this Science Outreach Catalyst Kit—Light: A Spectrum of Utility—should tell you that this kit focuses on how we use light as a tool in our daily lives. The inspiration for this theme came from the United Nations International Observances, which promote awareness and action on important political, social, cultural, humanitarian, or human rights issues all throughout the world by dedicating a day, week, month, or year to a specific topic or issue. The International Year of Crystallography (2014) and the International Year of Light (2015) strive to promote education on scientific inquiry and its uses, such as how crystallography underpins much of modern technology and how light-based technology serves us now and in the future. As such, the two main overarching questions of this SOCK are "How do we use light every day?" and "How can light tell us about matter and its structure, and why does structure matter?"

The SOCK is an excellent way to start or bolster your chapter's outreach programs. However, to ensure your outreach events are clear, informative, and entertaining, your chapter should sit down with the SOCK and work through all of the activities before doing an outreach event. Take it from us; it's better to figure out what you don't know before you step into the classroom, as students will ask good questions about the activities during the outreach event. Make sure you're prepared! Don't miss out on this opportunity to show young students some of the amazing things we can do with light.

This SOCK is not all-inclusive. We encourage you to design new activities and lessons related to the topics. In fact, we are confident that your chapter can create new outreach activities using the enclosed materials or items already in your physics department. We would like to hear about how you use the SOCK and what new ideas you come up with. Please be sure to send us reports, pictures, and videos about your outreach events. Let us know what works and what doesn't so that new generations of SOCKs can evolve to promote even more excitement about physics.

Thank you for your commitment to helping spread physics within your community. Please reach out to us at sps@aip.org with your outreach stories or any questions you may have!

Sincerely,

Kearns Louis-Jean, Xavier University of Louisiana, Class of 2015
Mark Sellers, Rhodes College, Class of 2015
SPS Summer SOCK Interns 2014

About our Partner: NIST

The 2014-15 SOCK is brought to you in partnership with NIST, the National Institute of Standards and Technology, and its Summer Institute for Middle School Science Teachers. Founded in 1901 and now part of the U.S. Department of Commerce, the National Institute of Standards and Technology (NIST) is one of the nation's oldest physical science laboratories. Congress established the agency to remove a major handicap to U.S. industrial competitiveness at the time—a second-rate measurement infrastructure that lagged behind the capabilities of England, Germany, and other economic rivals. Today, NIST measurements support the smallest of technologies—nanoscale devices so tiny that tens of thousands can fit on the end of a single human hair—to the largest and most complex of human-made creations, from earthquake-resistant skyscrapers to wide-body jetliners to global communication networks. NIST's mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.

Planning an Effective Outreach Event for your Chapter

The SPS SOCK is designed to be a starting point for science outreach carried out by your chapter in your community. The SPS SOCK contains the equipment and instructions for a few activities, but we also include suggestions and tips for planning a successful outreach event.

Checking for interest in your chapter

Before organizing an outreach activity, talk with your chapter to determine willingness to participate. Outreach requires a commitment of time for the events as well as preparation, but there are many benefits for students who participate! Presenting physics to younger students or even peers can be really fun! More importantly, when physics students present challenging concepts in order to educate and excite others about physics, the students learn while teaching! Taking the time to perform professional service provides immediate rewards in the "WOWs" that you get from the group, but also long lasting rewards when students can list service and leadership experiences on their resumes.

Planning an outreach event

Talk to your chapter advisor

Before contacting the schools and organizations to schedule any events, you should talk with your chapter advisor about the idea. Your advisor may have advice and access to resources that will help support your ideas. Also talk with your physics and education department faculty to see if there are already existing outreach programs at your school in which your chapter might participate. You want the support of faculty mentors in your outreach efforts!

Take out, or stay in?

In your discussions with advisors on campus, you will need to decide whether your chapter should go out into the community or to other groups on campus, or if your chapter should invite those groups to you. Both of these are meaningful ways to present sciences outreach activities, and what you do should depend on your chapter's interest, space and time.

Determine which lessons to present in outreach events

Once you have discussed the possibilities with advisors and your chapter, you are ready to plan some demonstrations and activities. What activities you present during an outreach event should be based on the budget and available materials and supplies, time and location constraints, and interest of the volunteers. Check around the department for items that you might be able to borrow if budget and supplies are an issue.

Next steps

Find willing participants!

Once you have decided to hold an outreach event, consulted with advisors, and decided on your program, it is time to find willing participants. Contact the math, science, and technology teachers in your local school districts to let them know you are interested in putting on science events for their students. Also, consider contacting local youth organizations such as Boy and Girl Scouts, 4H, and YMCA to see if they have any interest; these groups are often willing to come to you.

Get all the details

When scheduling an event, make sure to get all the specifics. When dealing with any group, on campus or in the surrounding community, you need to know:

- name of a contact person
- contact information for that person (email AND phone, address)
- anticipated number of students
- age of students
- any special requests for science topics to be covered

When taking your outreach off campus, you will need to know something about the space:

- the general layout of the space where you will present your outreach
- availability of electrical outlets and/or water/sink (if needed)
- availability of any other equipment that you might use and not want to carry (for example, extension cords, power strips, projectors, etc. – all dependent upon the particulars of the presentation)
- time constraints (allow time for participants to get settled and for a meaningful program closing/wrap-up)
- any special considerations or special needs of the participants. Try your best to address these concerns ahead of time, and if you need help, talk directly to the teacher or participant.

Ensure adequate transportation to and from the event for volunteers

Whether going in one vehicle or traveling separately, if your chapter is leaving campus it is a good idea for the outreach leader to confirm the travel arrangements with each volunteer. You should check with your advisor to make certain that you are abiding by any school policies that govern student travel, since SPS students are representing the department as outreach volunteers.

Send reminders

It is a good to send reminders to volunteers about upcoming events. An email or text message reminder is never a bad idea. You might consider making a flyer for each outreach event or keeping an outreach calendar in the student lounge or some other common area where volunteers congregate. Also, it is a good idea to check-in with your event contact person a few days before the event to verify that everything is in order.

Practice!

Test all activities/experiments/demos at least twice! Make sure all the volunteers are familiar with the lessons and equipment. Verify that everything is ready and prepare your equipment the day before. Rehearse the order of presentation and **write it down**. Make sure all presenters have an order of events beforehand.

Be prepared!

Pack up and do a complete inventory check well before the departure time if going off campus. Be sure to take a small "repair kit" and other supplies like pens, paper, scissors, extra batteries and tape.

Follow up after an event

Make sure that every outreach event is a learning experience, not just for the participants, but for your chapter members as well. Below are a few things that you should do ***after*** an outreach event:

- Debrief and evaluate: Do a post evaluation of your outreach event to discuss how things went and how to do better next time.
- Repair and or reset: Make an inventory of any supplies that were used up and will need to be replaced for the next event and repair any broken equipment immediately following an outreach event. Waiting until just before the next event to check the status of supplies or repair equipment is a bad idea.

Outreach is a customized activity for each chapter

The above notes are for any general outreach program for a chapter. When using the SPS SOCK, we encourage you to modify the lessons to best fit the needs of each specific outreach event that you have planned. We encourage volunteers to find personal experiences, real life examples and questions to help teach these principles. We have included example questions and real life connections that can be used as a starting place.

We hope this kit helps you to start or expand your outreach program and truly serves as a **catalyst** for the development and use of new activities.

Above all, physics should be fun, so have fun! And please share your outreach stories and let us know how it's going. You can contact us at ***sps-programs@aip.org****.*

How to use the SPS SOCK

The SPS SOCK is a “starter kit” for chapters that do not have a lot of experience with outreach events, or for chapters that do have experience but are looking to have more directed, hands-on activities for groups. While the activities are intended to convey some lesson or concept about physics, the hope is that participation in the activities will be fun for both the participants and the presenters and, for both groups, stimulate interest in the study of physics.

It would be impossible to complete all of the activities in an SPS SOCK in a single outreach event. If your chapter has an ongoing relationship with a classroom or group, you might consider doing a series of activities at each meeting. For a single outreach event, you should plan for no more than 45 minutes -1 hour of activities. By reading through this manual with the SOCK contents, you will get an idea of which activities will work best for your outreach events.

Things to consider

Determining which of the SPS SOCK activities to select for your outreach event will depend on:

- Time allotted for the activity. All time estimates are ±10 minutes at best. The best way to gauge time is to run through the activity with someone who has not seen it before.
- Age group or grade level of the participants.
- The space you have available (for example, some activities work best with tables and others in open spaces).
- The science background of the class and/or preference of the teacher. Some teachers prefer activities that align with their curriculum so they may request that you cover certain topics.
- Size of the group of participants. Small groups can sometimes go more in-depth with activities, but can take longer unless you have enough volunteers to station one presenter with each small group. Presenting to a larger group sometimes goes a little faster since there is less opportunity for interaction with individuals, but you may need more transition time between activities. If you do end up having several small groups, you may need to purchase additional materials to ensure that each group has what they need.

Using time effectively

We have included estimated times for each of the activities, but the time ranges can vary significantly depending on the skill level of the participants and the experience of the presenters. We recommend:

- Plan extra time for an opening and closing so that volunteers can introduce themselves and participants have time to ask questions – *about 10 minutes at the start and at the end.*
- Read through the activity carefully and do a few practice runs through the activities before the outreach event. In the practice note any additional equipment or supplies that might be needed for the activity.

What's in the SPS 2014 SOCK

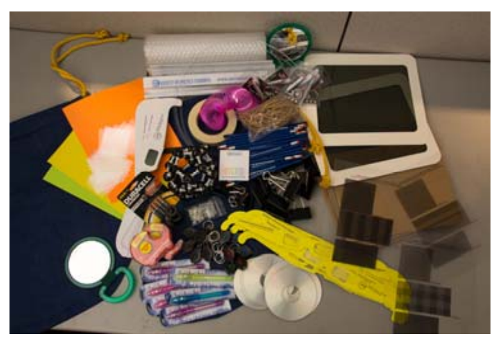
Your SOCK, most of which is actually packed inside a large denim SOCK, should contain the following components. Please check the contents carefully and alert the SPS National Office (at sps-programs@aip.org) about any missing parts.

Table 1: Contents of the SPS 2014 SOCK (Packing list)

✓	Quantity	Item	✓	Quantity	Item
	1	Slinky		6	Medium Binder Clips
	1	Green Laser		1 strip	Bubble Wrap
	1	Roll of Masking Tape		12	SPS Rulers
	2	Large Polarizers		60	SPS Pencils
	50	UV Beads		6	Fiber Optic Cables
	1	UV LED Flashlight (and batteries)		3 sheets	Fluorescent Paper
	6	"Invisible Ink" Pens		6	Cardboard Sheets
	6	CDs		1	Linear Diffraction Grating Printout
	6	Red Lasers		1	Square Diffraction Grating Printout
	1	Diamond Molecular Kit		1	Hex. Diffraction Grating Printout
	1 box	Large Binder Clips		2	Mirrors
	1 bag	Rubber Bands		1 pack	Post-it Notes
	30 pairs	Diffraction Glasses		2 rolls	Cellophane Tape
	30 pairs	Polarized Film Glasses		36	Transparency Squares
	1	Worksheet folder		1	Wavelength Shifting Fiber
	12	LEDs		1	SOCK special guide

Other items that will be useful with the SPS 2014-15 SOCK (not included)

- Clear plastic soda bottle
- Printout of Morse Code
- Microwave
- Microwave safe plate
- Marshmallows, small chocolate chips, or cheese slices
- EM spectrum handout or slide
- $20 bill
- Driver's license
- Laundry soap
- Tonic water
- Overhead projector or other bright white light source
- Discharge lamp
- Gas tubes (Hydrogen, Helium, and Neon are recommended)



The 2014-15 SOCK materials.

Activities and explanations in the 2014-15 SPS SOCK

Demonstration Name	*Expected Time (min)*	*Appropriate Grade Level*
Light fountain	20	All ages
How microwaves work	10	Elementary school
Speed of light in a microwave	25	Middle to high school
Fluorescence	15	All ages
Polarized "stained glass"	20	All ages
Pencil diffraction	15	All ages
Diffraction patterns (low/high)	40	Elementary school / Middle to high school
Structure matters	20	All ages
Excited gases (supplemental)	20	All ages

Notes

- In the text, items in ***blue ink*** are suggestions for what you might say out loud.
- For best results with these activities, you will need to be able to control the amount of light in the room, as well as have accessible surfaces (ie, desks or tables) where students can perform the activities.
- If you are intending to use this SOCK in a large outreach setting, the activities outlined here work best in a "stations" configuration, where your chapter selects 2-5 demonstrations to lead simultaneously and small groups rotate through each station.
- You are encouraged to go through all of the activities and chose the ones that you think will work best for your audience and in the location that you will be using, but we suggest a few possible groupings for classroom visits.

Suggesting grouping for a one hour classroom visit focused on Light as a Tool:

Elementary School	**Middle School**	**High School**
Fluorescence	Light fountain	Light fountain
Polarized Stained Glass	Polarized Stained Glass	Polarized Stained Glass
How microwaves work	Speed of light in a microwave	Speed of light in a microwave
Light Fountain		

Suggesting grouping for a one hour classroom visit focused on diffraction:

Elementary School	**Middle School**	**High School**
Basic Diffraction Introduction	Basic Diffraction Introduction	Basic Diffraction Introduction
Diffraction Patterns (Low)	Diffraction Patterns (Low/ High)	Diffraction Patterns (High)
Structure Matters	Structure Matters	Structure Matters

SOCK Activities Part 1:

Light as a Tool

Light fountain: Light as a tool for communication

Expected Time: 20 min
Grade Level: All

Objective: Students will be able to…

1. Visualize how light travels in a straight line.
2. Relate the idea of light traveling in a straight line to how information can be transmitted

Materials:

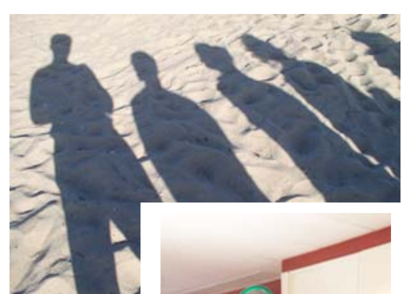
1. A clear plastic soda bottle, empty, with a hole about the diameter or a pencil tip poked in one side (not provided)
2. Hand held mirrors (2)
3. Post-it notes
4. Masking tape
5. Green laser pointer
6. Fiber optic cables
7. LEDs
8. Optional: Light Fountain Worksheet (1 per student)
9. *If desired: A printout of Morse Code* (not provided)

Introduction:

Light can be used for transmitting information and communicating, but it can be a difficult to harness without the proper equipment. This demonstration showw how light behaves like a wave and, because of that, how we can harness one of its properties (traveling in a straight line) for sending information.

Preparation:

1. Put a strip of tape about half an inch long on the bottle about an inch above the base.
2. Use a tack or pin to poke a hole in the bottle through the tape. Widen the hole so that it is about the diameter of a pencil so that water can flow out easily.
3. Cover the hole with another piece of tape (to keep the bottle from leaking) and fill the bottle with water.
4. Store the bottle in a bucket in case it does leak.



Human shc

Procedure:

Part 1: Light in a straight line

1. OPTIONAL: Have students complete section 1 of the worksheet.
2. *How does light create shadows?* Use an LED and your hand to create a shadow on a wall. Encourage the students to think about why a shadow has the shape that it does.
3. Write "Light is cool" or draw a shape on a post-it note and stick it to the back collar of someone in the group, but don't let that person see the

Reading a post-it using mirrors.

writing. *How can you use these mirrors to see what is written on your back?*

4. Give the person two mirrors and have him/her try to arrange them so that the writing is visible. The ideal set-up is if the person with the post-it note holds one mirror in front of his/her shoulder and the other behind the same shoulder.
5. *Why can we use mirrors to help direct light?* Mirrors work through the law of reflection, which means light will bounce off the mirror at the same angle it hit the mirror (the angle of incidence equals the angle of reflection). The law of reflection only holds because light travels in a straight line!
6. *What are some other ways that we can make light go where we want it to go?*

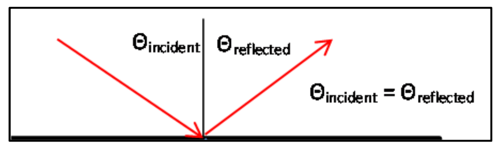


Diagram of light reflecting in a straight line.

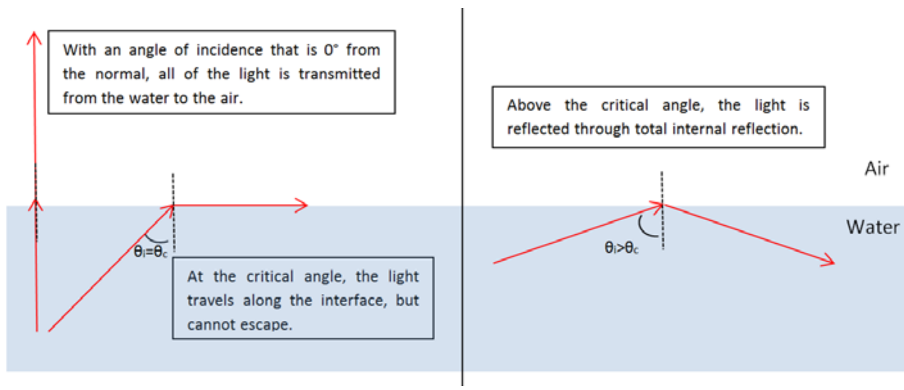
Part 2: Total internal reflection

5. Lift the bottle of water out of the bucket and hold it up. *What do you think will happen when I remove the top layer of tape?* Remove the tape (be sure the bottle cap is off) and watch the water flow for a few seconds, then replace the tape.
6. *What do you think will happen if I shine a laser from the back of the bottle through the hole, and then remove the tape?* Turn on the laser and shine the beam into the bottle—this works best in a dark room. Students should notice that the water inside the bottle starts to glow with the light.
7. Remove the tape to start the stream again. You may need to adjust the position of the laser to ensure that the beam travels down the stream. You can place your hand in the stream to "catch" the light, showing how the light actually traveled down the stream. If the stream breaks up, you should be able to see light glowing in the water droplets.
8. *Can anyone guess how the light traveled down the stream of water?*

A light fountain in action.

Part 3: Understanding fiber optic cables

1. Distribute the fiber optic cables and LEDs, and have student shine the LED into one end of the fiber and see what happens. *How could you guide light around an obstacle using a fiber like this? How does this relate to the light shining through the stream of water?*
2. *Does the light escape anywhere other than the ends of the cable?* Explain the idea of total internal reflection. (Light travels in a straight line until it hits a coating on the cable. It is reflected and continues bouncing all the way down the cable.) This is also how the laser light travels down the stream of water. It is reflected by the air-water boundary. (You can think of light as being caught inside of the water stream. Instead of coming out the other side, it hits the air-water boundary and bounces back into the stream. It keeps doing this until it reaches the end of the stream.)



3. OPTIONAL: Have students complete section 2 of the worksheet.
4. *How can we use this kind of technology (fiber optic cables) to transmit information?* After taking a few responses, suggest flashing the light on and off at one end of the cable. Distribute the Morse Code sheets to the groups and have small groups work together to transmit words to each other via the fiber optic cables. Explain that the internet and television cables work much the same way, except the cables are bigger (many fibers are bundled together) and the pulses of light are much more rapid.

How microwaves work: Light as a tool for cooking

Expected Time: 10 min
Grade Level: Elementary

Objective: Students will be able to…

1. Understand that most light is invisible, but can still be useful to humans
2. Show that standing waves in a microwave create hot spots on food

Materials:

1. A microwave (not provided)
2. A microwave safe plate or cardboard square (not provided)
3. Marshmallows, small chocolate chips, or cheese slices (not provided)
4. Slinky
5. EM spectrum handout or slide (not provided)

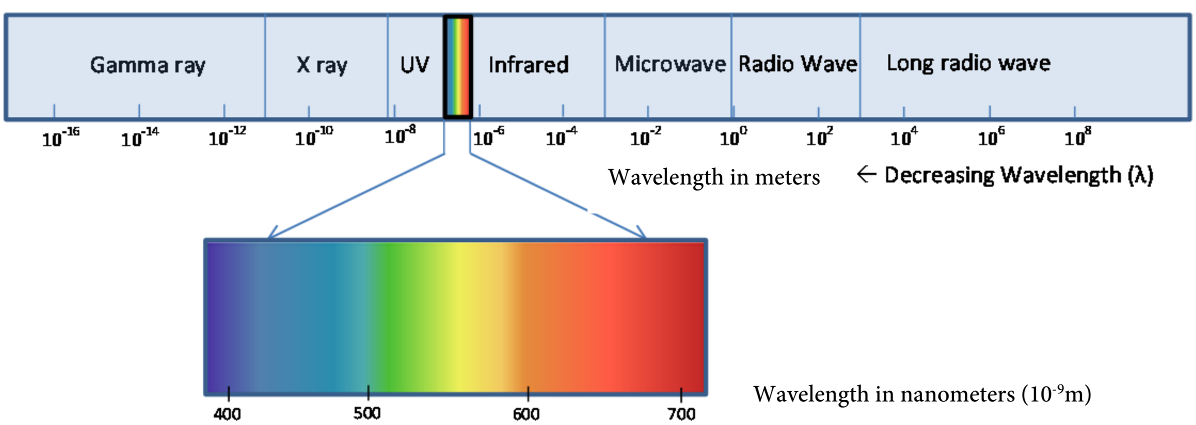
Introduction:

We use light every day – you might not realize it, but light can cook our food for us! A microwave converts electricity into a type of light called *microwave radiation*, which heats up the water inside of our food. If you've cooked on a campfire before, you have used infrared radiation to cook your food.

Procedure:

Part 1: Light and the EM Spectrum:

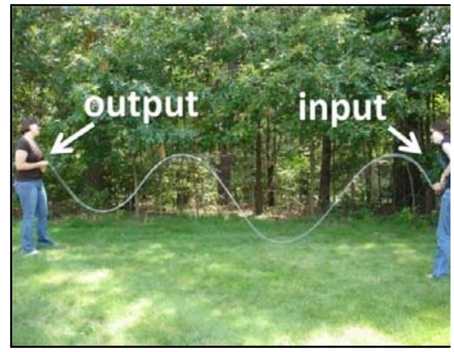
1. *What objects emit light? What are some different kinds of light?* Pull out a picture of the EM spectrum to show the students. Point out all of the different types of light and where they fall on the spectrum.



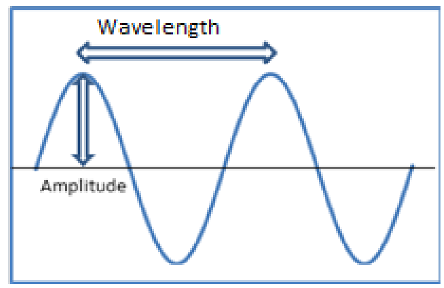
2. *What are some ways we use the light you mentioned?* If not mentioned, be sure to point out how microwaves use microwave radiation to cook food. *But how exactly does it work?* Look for an answer involving "light has energy".

Part 2: Standing wave demonstration:

1. Have two student volunteers hold either end of a spring and stretch it out. Have one volunteer wiggle his/her end up and down while the other holds his/her end still. *What do you see? What are the parts of a wave? Which parts of the wave do you think have the most energy?* Note that the wave appears to stay in the same place—it is not moving through the spring. This is called a standing wave.



Standing wave demonstration (photo courtesy of the 2008 SOCK).



Part 3: Standing waves in a microwave:

1. Cover the microwave safe plate with one layer of tightly packed marshmallows or chocolate chips (or slices of cheese). This will serve as our standing wave detector, since microwave ovens create standing waves. That's why microwaves don't always cook evenly—the wave will peak at particular points, creating hot spots.
2. If you have the option, turn off the microwave's turntable. **Otherwise, remove the turntable**, as a spinning turntable will mitigate the desired effect. Note that some commercial microwaves do not have spinning turntables and still claim to cook evenly. If you plan to use one of those, be sure to test it first and make sure the hot spots are easily identifiable.
3. Place the plate of marshmallows (or cheese or chocolate) in a household microwave. *What do you think will happen to the food in the microwave?*
4. After a minute or so (you'll want to test this with your particular microwave first to find the optimal time), remove the plate and have the students observe the food. Be sure they notice that some places are more melted than others. *Why are there melted splotches on the plate?*
5. *A microwave creates standing light waves in the microwave part of the spectrum. Which parts of a standing wave have the most energy? Which parts have the least? What does this tell us about how a microwave works? Where do you think the hot spots come from?*
6. *Why doesn't the plate the food is on melt?* Most, if not all, of our food has water in it. When the microwave passes through the food, it will start to vibrate the water particles inside, generating heat. Glass, ceramic, and plastic do not have water inside of them, so the wave passes through harmlessly.

History of the microwave:

The microwave oven was first introduced in 1940 when Percy Spencer, a researcher for Raytheon, noticed that a chocolate bar melted in his pocket during his experiments with a cavity magnetron. He placed other food items, like popcorn, near the cavity magnetron. After a few moments, the popcorn started popping in front of him. The first microwave weighed 750 pounds and cost approximately $5000. (Source: http://science.howstuffworks.com/innovation/scientific-experiments/9-things-invented-or-discovered-by-accident2.htm)

Speed of light in a microwave: Light as a tool for measurement

Expected Time: 25 min
Grade Level: Middle to high school

Objective: Students will be able to…

1. Visualize the concept of a standing wave
2. Show that standing waves in a microwave create hot spots on food
3. Calculate the speed of light by measuring the distance between hot spots

Materials:

1. A microwave (not provided)
2. A microwave safe plate or cardboard square (not provided)
3. Marshmallows, small chocolate chips, or cheese slices (not provided)
4. EM spectrum handout or slide (not provided)
5. Ruler
6. Slinky
7. Optional: Speed of Light in a Microwave Worksheet (1 per student)

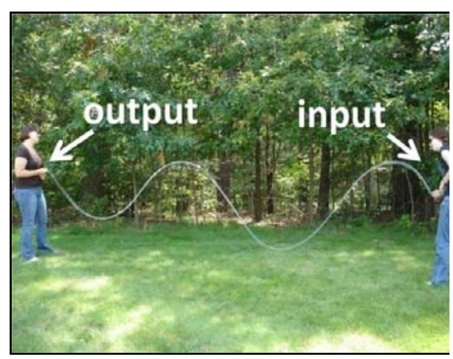
Introduction:

We use light every day. You might not realize it, but light can cook our food for us! A microwave converts electricity into a type of light called *microwave radiation*, which heats up the water inside of our food. We cannot see microwaves because their wavelengths are too long (their frequencies are too low) for our eyes to detect. Microwave ovens can also be used for another purpose—measuring the speed of light. The speed of light in a vacuum, commonly called *c*, is a constant that people use to measure distance. The definition of a meter is the distance traveled by light in $\frac{1}{299792458}$ seconds.

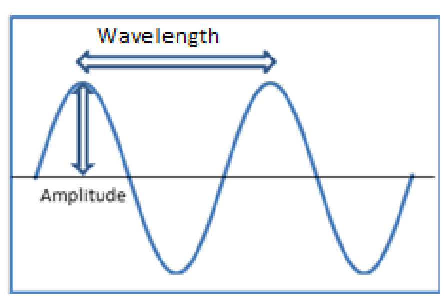
Procedure:

Part 1: Standing wave demonstration

1. Have two volunteers hold either end of the spring and stretch it out. Then have one volunteer wiggle his/her end up and down while the other volunteer holds his/her end still. *What do you see? What are the parts of a wave?* Note that the wave appears to stay in the same place—it is not moving through the spring. This is called a standing wave.
2. *How can we measure wavelength?* Make sure the students understand that wavelength is a measurement of a whole cycle—from peak to peak or valley to valley. If necessary, draw a cartoon wave and demonstrate the proper measurement technique.
3. *Light is a wave. If we know the wavelength and the frequency (or how many crests of the wave cross a certain*



Standing wave demonstration (photo courtesy of the 2008 SOCK).



point per second) of light, we can multiply them together to find c.

4. Optional: Have students complete section 1 of the worksheet.

Part 2: Light, waves, and the EM Spectrum

1. Optional: Have students complete section 2 of the worksheet.
2. *What objects emit light? What are some different kinds of light?* Pull out a picture of the EM spectrum to show the students. Point out all of the different types of light and where they fall on the spectrum.
3. *Light travels in waves, but how can we measure the speed of light if we can't see the waves wiggling in front of us?*
4. Turn the lights off in the room. *Tell me when you see the lights turn on so we can figure out how fast light travels.* Turn the lights back on and start collecting answers. *Well, that's not a good method!*
5. *Even if we know the wavelength of a wave, what do we need to calculate the speed?* The frequency.
6. So, we need to find something that emits light with a specific frequency and figure out how to measure the wavelength in order to calculate the speed of light. *Does anyone know of any kitchen appliances that use light?*

Part 3: Speed of light in a microwave (Section 3 on worksheet)

1. Cover the microwave safe plate with one layer of tightly packed marshmallows or chocolate chips, or a layer of sliced cheese. *This will serve as our standing wave detector, since microwave ovens create standing waves.* That's why microwaves don't always cook evenly—the wave will peak at particular points, creating hot spots.
2. If you have the option, turn off the microwave's turntable. **Otherwise, remove the turntable**, as a spinning turntable will mitigate the desired effect. Note that some commercial microwaves do not have spinning turntables and still claim to cook evenly. If you plan to use one of those, be sure to test it first and make sure the hot spots are easily identifiable.
3. Place the plate in the microwave and set it for approximately a minute (you'll want to test this with your particular microwave first to find the optimal time). While the microwave is running, explain that the microwave is creating standing waves and the food is absorbing that energy. When things absorb energy, they get hot (just like you when you wear a dark shirt on a sunny day).
4. Remove the plate. *What happened to the marshmallows?* If the turntable was successfully disabled, there should be burnt/melted spots on the plate. That's how we know we created standing waves!
5. *How can we use this information, if we know the hotspots are related to the standing wave in a microwave? Recall what a standing wave looks like and how we measured wavelength. Does the distance between those two hotspots make a full wavelength?* They actually make *half* a wavelength, since the wave "peaks" every half wavelength. We need to double that measurement to get a full wavelength.

6. *How can we measure the wavelength from this plate?* The best method is to approximate the middle of the hot, melted spot and

measure to the middle of the next hot, melted spot, although your students may have other ideas. Burned spots work okay, but are not as periodic as the melted spots. If your microwave is operating at 2450 MHz, the distance should be about 6cm between melted spots.

7. Optional: Have students complete section 3 of the worksheet.
8. Have students measure the wavelength in groups, record their answers in a common area, and average their measurements. Be sure to discuss any outliers first and decide whether any measurements need to be redone. Then have them convert the distance into meters if they measured in other units.
9. *So, we have wavelength, but what are we missing to calculate the speed?* Thankfully, microwave manufacturers give us the frequency of the microwave on the back panel! Be sure to convert the given frequency into *Hertz*. That's all we need to calculate the speed of light!
10. Write down the equation for the speed of light ($\boldsymbol{c = f\lambda}$) and lead the group through solving for *c*. *How close is this to the actual speed of light in a vacuum? Where might errors have been introduced? What could you do to get a more accurate result?*

(Note: Students can make the measurement and do the calculation in small groups if their math skills are strong enough. Then you could have groups compare their answer for *c* and discuss how close they were to the actual results.)

11. *So how can we use the speed of light?* (See "Explanation" below.)

Explanation:

All types of light travels at the same speed through the same medium—everything from radio waves to microwaves to visible light to x-rays. Since the speed of light is a constant, scientists use it as a *standard*. This means the speed of light is the same for everyone, so everyone has a universal tool for measuring distance. If you measured the length of something and wanted to share those measurements with other people, you would want to make sure you used the same type of ruler. Otherwise, the measurement wouldn't make sense! Scientists use the speed of light to determine the meter, which is the distance traveled by light in $\frac{1}{299792458}$ seconds. The typical 12 inch rulers represent the distance traveled by light in a billionth of a second. Scientists also use a really long distance called a *light year*, which is about 6 trillion miles, to talk about far away stars are from Earth.

History of the microwave:

The microwave oven was first introduced in 1940 when Percy Spencer, a researcher for Raytheon, noticed that a chocolate bar melted in his pocket during his experiments with the cavity magnetron. He placed other food items, like popcorn, near the cavity magnetron. After a few moments, the popcorn started popping in front of him. The first microwave weighed 750 pounds and cost approximately $5000. (Source: http://science.howstuffworks.com/innovation/scientific-experiments/9-things-invented-or-discovered-by-accident2.htm)

Fluorescence: Light as a tool for making the invisible visible

Expected Time: 15 min
Grade Level: All

Objective: Students will be able to…

1. Explain how we see color
2. Understand how everyday items can fluoresce under UV light
3. Think of ways we can use fluorescence and understand how it is currently used

Materials:

1. UV LED Flashlight (be sure to put in the batteries)
2. "Invisible ink" pens with UV LED
3. Fluorescent paper
4. Optional:
    - UV Beads
    - $20 bill (not included)
    - Driver's license (not included)
    - Laundry soap (not included)
    - Tonic water (not included)
    - Other items that fluoresce

Introduction:

We use light to see things around us. Visible light, however, is a small fraction of the whole spectrum of light in the electromagnetic spectrum. Light we cannot see is still highly useful to us every day—radio waves allow for communication, microwaves help cook food, etc. The sun gives off all kinds of light, including ultraviolet (UV) radiation that can be dangerous to humans without the proper protection. However, we can still harness UV light to help us in day-to-day life.

Note: Looking directly at ultraviolet light can be harmful to your eyes. Instruct students to only point the UV lights at the objects you give them to investigate (not at people)!

Procedure:

Part 1: Invisible ink and secret messages

1. Before this demonstration, take the invisible ink pens and write messages on sheets of white paper.
2. When students arrive, distribute the messages and invisible ink pens. *We've written something down on each of these papers, but we used invisible ink. How are you going to figure out what we wrote?*
3. Give students some time to figure out how to read the messages. If need be, prompt them by mentioning that the invisible ink pens come equipped with something that might "shed light" on the puzzle.

4. *What was written down and how did you figure it out?* If the students say that the flashlight was responsible, follow up and ask them why the flashlight helped. And, if the students say “Magic!” be sure to say “No, it’s science!”

Part 2: Explanation of fluorescence

1. *When you shine the light on the invisible ink, the ink glows. We call this fluorescing. Does anyone know what it means for something to fluoresce?* Something fluoresces when it absorbs light of one color and emits light of another color. In the case of the invisible ink, the ink absorbs the UV light from the pen and fluoresces in the visible part of the spectrum.
2. *What type of light is responsible for giving us sunburns?* Again, UV light. Since the sun gives off ultraviolet light, things that fluoresce in response to UV light also look really bright in the sunshine.
3. *How can we figure out if something is fluorescent or not?* Turn off the light—explain that now there is no visible light in the room—and shine the UV light on a piece of fluorescent paper. It should light up significantly, and if the room is dark enough, it will look like the paper is glowing. *We know that this flashlight is giving off ultraviolet light (so don’t look directly at the beam!), so the paper is fluorescing just like the invisible ink. You can do this with other fluorescing materials as well.*
4. Give students 5 minutes to explore the fluorescence of different objects under UV lights.

Part 3: Brainstorming how to use fluorescence

1. Have your students take about 5 minutes to talk with each other about how they could use fluorescence to create a new invention, product, or tool. *What is one invention/product/tool that your group came up with?*
2. Here are some examples of how we use fluorescence today:
    a. Shine the UV light on white clothes or white paper to show that it fluoresces. *Does anyone know why manufactures would make clothes and paper that fluoresce?* These things fluoresce because the “white” color of untreated clothes and paper actually looks yellow—imagine old clothes in the attic. So, manufacturers include a chemical that fluoresces blue because when blue and yellow light mix together, we see white (they are complementary colors). Make sure your students remember that white light is made up of all colors, but you can also make white by mixing two opposite colors of light together. ***Be careful**: This is not the same for paints! These are two different processes.*
    b. *The US government uses UV light to check if things are real or fake.* If you have a $20 bill or a driver’s license with UV tags, pull it out and shine the flashlight on it. The $20 bill has a green band on the left side that will light up under UV light. These hidden images are hard to counterfeit.
    c. *Fluorescent lights work by sending a current through mercury vapor, which glows in the UV spectrum. If we coat the inside of the light bulb with a fluorescent material, we can convert that UV light into visible light very efficiently!*

Polarized "Stained Glass": Light as a tool for understanding matter

Expected Time: 20 min
Grade Level: All ages

Objective: Students will be able to…

1. Describe how polarization works
2. Understand how white light passing through layers of tape is separated into various colors

Materials:

1. Two large linear polarizers
2. Transparency squares (one per person)
3. Cellophane tape
   If you need more than what is included in the SOCK, note that Scotch tape doesn't work well, cheap generics seem to work best. Make sure the tape is clear (glossy) and not frosted and TRY it before using for this activity.
4. Polarizing glasses (one pair per person)
5. Slinky
6. Rulers (2)
7. Overhead projector or other bright white light source (An overhead projector works the best in a classroom demonstration.)

Introduction:

Polarization of light is critical for the operation of many modern technologies, including LCDs (liquid-crystal displays) and most current 3-D displays. Two of the general types of elements that control polarization are polarizers and wave plates. Polarizers act by passing light with the desired polarization while blocking all others, and wave plates act by rotating one polarization into another. Materials that naturally act as wave plates are called "optically active." In some materials, such as the liquid-crystals used in LCDs, the amount of rotation can be controlled by an electrical signal. By placing these elements between two polarizers, an LCD acts much like a controlled version of the "polarized stained glass" to be constructed below.

In this activity, the phenomenon of optical activity and the wavelength dependence of electric field rotation are demonstrated by using a simple and common optically active material: cellophane tape. By applying multiple layers of cellophane tape to a clear transparency sheet, we see that the thickness of the tape has an effect on the color of the light that passes through when the tape is "sandwiched" between two polarizers.

Note that this demonstration deals with complex physics, some of which is likely to be inaccessible to the students you are working with. That's okay! You don't have to go into all of this detail.

Procedure:

Part 1: Visualization of polarization

1. *Who has heard of polarized sunglasses? What do you think the term "polarized" means?* Light is a transverse wave. This means that the "wiggles" (oscillations of the electric and magnetic fields) of the light wave occur in the plane perpendicular to the direction that the light is travelling. Regular (i.e., unpolarized) light will wiggle randomly in all directions in that plane. However, light that is reflected off of smooth surfaces like roads and lakes tend to wiggle in the same direction. This causes the annoying thing we call glare. Polarized sunglasses help filter out glare by blocking light that is wiggling in this way.
2. *Should we demonstrate what this wiggling looks like?* Have 4 student volunteers come up to perform this demonstration. Have two students hold the spring on either end and create a standing wave. Instruct the other two to each take a ruler and work together to figure out how to stop the wave from reaching the other side. If done properly, the students should line their rulers up to make a slit that is perpendicular to the plane of polarization of the standing wave. These rulers are acting like polarizers. They filter out light that is wiggling in a certain direction.

2008 SPS interns model the "polarization" of a standing wave wigging side-to-side with meter sticks. Photo courtesy of the 2008 SOCK.

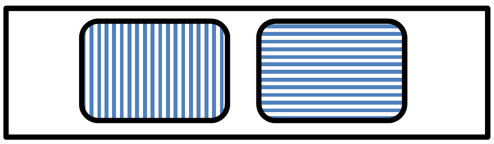
Part 2: Demonstration of linear polarizers

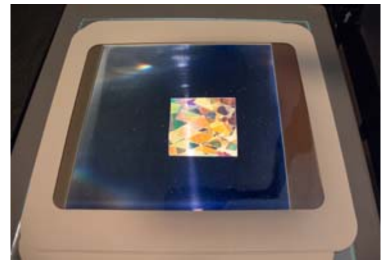
1. Show the class one of the large polarizers. *What do you think will happen when I hold this polarizer in front of a bright white light?* Demonstrate how a polarizer serves as a filter, blocking some of the light. You can do this by holding a polarizer in front of a window or bright white light (or by placing it on the overhead projector).
2. *What do you think will happen to the brightness of the light coming through if I put a second polarizer in front of the first one?* First, place the two polarizers so that the transmission axes are parallel. *Do you notice anything different about the brightness of the light?* The light should look somewhat dimmer after going through both filters, but nothing too dramatic. Next, slowly rotate one of the polarizers with respect to the other, allowing students to see that eventually (when the transmission axes of the polarizers are perpendicular) no light gets through. This should get some 'ooohs and aaahhs' from participants.
3. Explain that some materials can change light in ways that defeat the crossed polarizers by changing the polarization of the light that is between the polarizers. One of those things is ordinary tape – now it is time for them to explore.

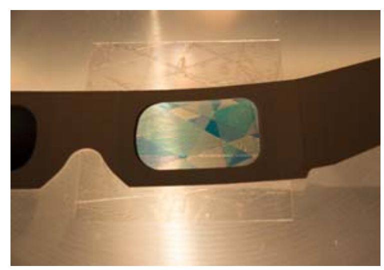
Part 3: Polarized stained glass

1. Distribute a transparency square to each student and a roll of cellophane tape to small groups of students. *Use pieces of tape to create a design on the transparency. You can use as many layers of tape as you would like, and orient them in any way you would like. Be sure to use multiple layers of tape in some places– at least 4 or 5.*

2. As the students finish their squares, they can take turns investigating what happens when their works of tape art are placed between the large polarizers.
   If you are using an overhead projector, place one polarizer on the projector and have the students lay their squares on top. Then have them rotate the second polarizer over the top and watch what happens.
   If you do not have an overhead projector, place one of the large polarizers on a table and place the tape creations on top. Then, have your students put on the polarizing glasses. These glasses have two linear polarizers oriented like this:



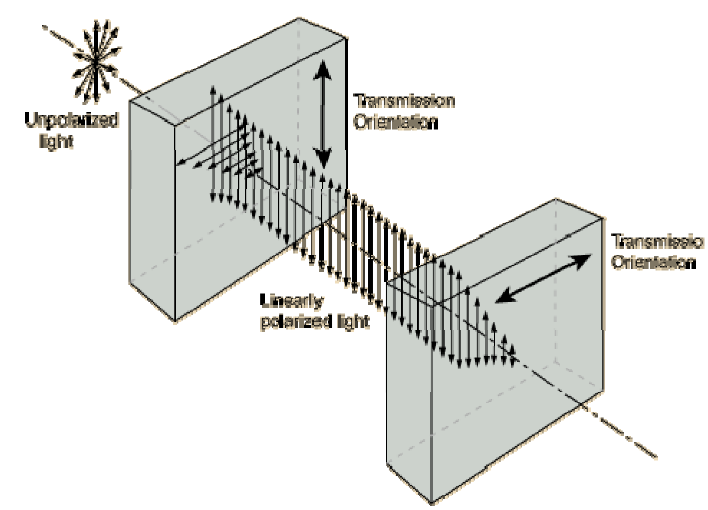




   That is, the transmission axes of the two linear polarizers are oriented perpendicular to each other. While wearing the polarizing glasses, have your students close one eye and look at their artwork, and then do the same with the other eye. They should be able to see the colors shift.
3. *What did you see? Were you surprised? Where do you think the colors came from? How do the colors change as you rotate the top polarizer?* The colors you see depend on several factors including the composition of the tape, the number of layers of tape, and the angle between the polarizers.

Explanation:

A polarizer filter out light that does not wiggle in a particular direction based on how the polarizer is oriented. When you cross two polarizers, you filter out all of the light. However, we see colors when pieces of tape are layered between the two polarizers. Each layer of cellophane tape acts like a wave plate, rotating the polarization of the light coming through the first polarizer. This allows some of the light to make it through the second polarizer. However, the amount of rotation varies with color—certain colors are rotated more than others when they pass through the tape. Also, the amount of rotation depends directly on the number of layers you use, so different thicknesses of tape



Crossed polarizers. Image used with permission from HyperPhysics by Rod Nave, Georgia State University. http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/polcross.html will rotate different amounts. Thus, the colors that make it through the second polarizer depend on its orientation and the thicknesses of tape used.

Additional Resources:

Wave plate explanation: http://video.mit.edu/watch/half-wave-plate-11863/
Polarization explanation: https://www.youtube.com/watch?v=KM2TkM0hzW8

SOCK Activities Part 2:

How can light tell us about matter and its structure, and why structure matters?

Pencil Diffraction

Expected Time: 15 min
Grade Level: All

Objective: Students will be able to…

1. Understand that light can be diffracted because it is a wave
2. Explain how slit width and orientation affect the diffraction pattern

Materials:

1. Pencils (2 per students)
2. Paper
3. Rubber bands (1 per student)
4. LED (1 per pair of students)
5. Pencil Diffraction Worksheet (1 per student)
6. OPTIONAL: Ability to show the following videos:
   -Simulation of single-slit: http://www.walter-fendt.de/ph14e/singleslit.htm
   -Simulation of double-slit: http://www.colorado.edu/physics/2000/schroedinger/two-slit2.html

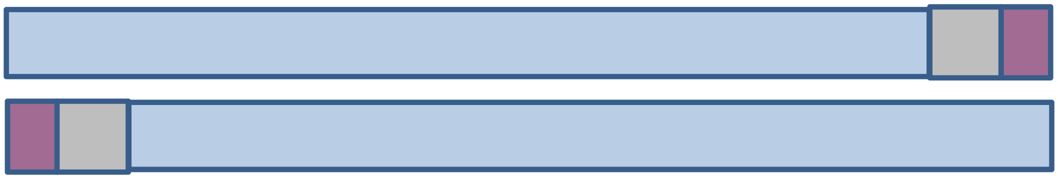
Introduction:

This activity introduces the concept of diffraction. While simulations may provide a conceptual ground for diffraction, this demo will allow the students to see how slit width will affect the light's appearance.

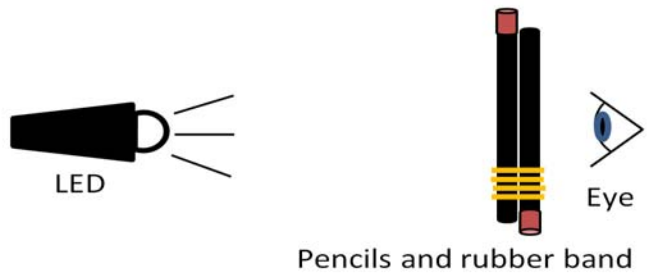
SPS intern Mark Sellers leads summer camp attendees through a pencil diffraction experiment.

Procedure:

1. Ensure that the students understand that light travels as a wave.
2. Have the students hold two unsharpened pencils in the orientation as shown below (eraser on top of tip) and wrap a rubber band around the pair.



3. Have students hold the pencil set perpendicular to the ground, an inch or two in front of their eyes. Then instruct them to close one eye and look through the space between the pencils at the LED. They should be 10 feet or more away from the LED for optimal effect.



4. *What do you notice?* Have them squeeze the pencils together to vary the width of the slit. *At any point do the pencils start to look hazy around the edges?*
5. Have students complete the "Observe" section of the worksheet or go through the questions below as a group.
6. *What happens to the light as the pencils get closer and closer together? Do you see a bar of light appear? Does the bar of light look solid or is it broken up?* Have the students sketch what they see; as detailed as possible.
7. Have students rotate the pencils so they are parallel with the ground and look at the LED through the horizontal slit. *How does the appearance of the bar change?* The diffraction pattern should now appear vertical instead of horizontal.
8. *Is there a connection between the pattern you see and how wide the slit is?* As the slit gets narrower, the pattern should spread out. Conversely, a wider slit should make a smaller pattern.

OPTIONAL higher level activity:

1. Have students complete the "Hypothesize" section of the worksheet.
2. *What do you think would happen if we looked at the light source through two slits that are close together, instead of just one? That is harder to visualize, so we will need to use the computer to help us.* Play the simulation. Note that if you use the simulation from the University of Colorado, be sure you set the "slit separation" bar all the way to the left to create a single slit. Then, adjust the slit separation to show what happens when we have two slits.
3. *What is happening? Where do the bars of light come from?* We can see what happens by looking at waves of water as they go through two slits, since light behaves like a wave.
4. Have students complete the "Discuss" section of the worksheet.

Explanation:

Bringing the pencils close together creates a single slit through which we can look at a light source. When light goes through a slit, it spreads out in a wide arc, almost as if the slit was the light source. The bright spot in the center looks like it traveled in a straight line from the source to our eye, but we see a bigger pattern with light and dark areas. When light spreads out in this way, sometimes the light waves will line up in ways that their energy adds together, this creates bright spots. At other times the waves line up in ways that cancel each other out, creating the black splotches. This is called "interference." As you add more slits, you get brighter, narrower spots.

Crystallography—Diffraction Patterns (Low level)

Expected Time: 40 min
Grade Level: All

Objective: Students will be able to…

1. Visualize the structure of diffraction glasses.
2. Predict the structure of a CD based on known diffraction patterns.

Materials:

1. Diffraction glasses (1 per group)
2. CD (1 per group)
3. Red laser (1 per group)
4. Ruler (2 per group)
5. Binder clips (2 large and 1 medium per group)
6. Cardboard sheet (1 per group)
7. Linear diffraction grating printout
8. Crystallography—Diffraction Patterns Worksheet v1 (1 per student)

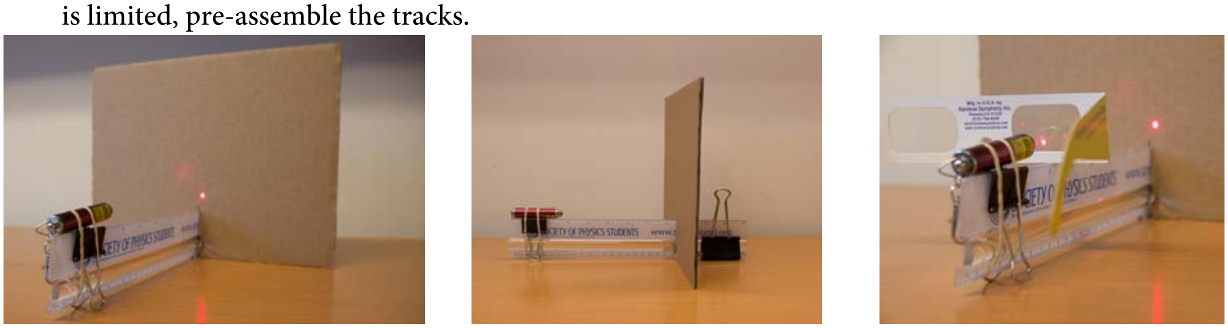
Introduction:

2014 is the International Year of Crystallography, which focuses on how we can use light to understand the structure of matter on the atomic level. This activity encourages students to think about how light can give us information about the structure of objects though diffraction patterns.
Be careful: This activity involves lasers. Be sure to explain the dangers of lasers and that improper use will result in the materials being taken away.

Note: We strongly recommended doing the pencil diffraction activity with students before doing this activity.

Procedure

1. Distribute the materials and help students assemble the optics track as shown below. If your time is limited, pre-assemble the tracks.



An assembled optics track.

2. Have each group shine a laser through one lens of the diffraction glasses and onto the cardboard screen. *What do you see? Does that look like something we looked at earlier?* Have students make a prediction about the structure of the "lenses" in the diffraction glasses based what they saw with the pencils and simulations. If necessary, talk them through coming to the realization that the diffraction glasses have really long, thin grooves running up and down through the lens, like multiple slits.
3. Have the students complete section 1 of the worksheet.
4. In front of the whole group, shine the laser through the blocks on the transparency of linear diffraction gratings. Start with the 100 lines/inch block and work your way towards the 150 lines/inch block. For each one, tell students the spacing and have them observer how the pattern changes *What is the relationship between line spacing and the spread of the laser pattern on the wall?*
5. Have the students complete section 2 of the worksheet.
6. Re-adjust the optics track so the screen is behind the laser. Mount the CD into a binder clip and put it at the end of the ruler.

The optics track reassembled for section 2.

7. *Shine the laser at the CD and look at the pattern that is reflected on the screen. What does this tell us about the structure of a CD? Does the pattern change with the orientation of the CD?*
8. *Compare the pattern from the CD with the pattern from the diffraction glasses. Which pattern is larger? What does that tell you about the line spacing between the two?*
9. Have the students complete section 3 of the worksheet.

Closing:

Crystallographers study the diffraction patterns created by different materials to understand their structure. However, they don't use red lasers; they use X-ray sources. X-rays have a very short wavelength. That wavelength is on scale with the width of an atom. We can use a red laser with the diffraction glasses and CDs because their structures are much bigger. If we tried to use X-rays on the CD or the diffraction glasses, the light would pass right through (not to mention we can't see X-rays)!

Crystallography—Diffraction Patterns (High level)

Expected Time: 40 min
Grade Level: High school

Objective: Students will be able to…

1. Visualize the structure of diffraction gratings
2. Calculate the line spacing in the glasses
3. Visualize the structure of a CD
4. Calculate the groove spacing on a CD

Materials:

1. Diffraction glasses (1 per group)
2. CD (1 per group)
3. Red laser (1 per group)
4. Ruler (2 per group)
5. Binder clips (2 large and 1 medium per group)
6. Cardboard sheet (1 per group)
7. Linear diffraction grating printout
8. Crystallography—Diffraction Patterns Worksheet v2 **OR** v3 (1 per student, see note below)

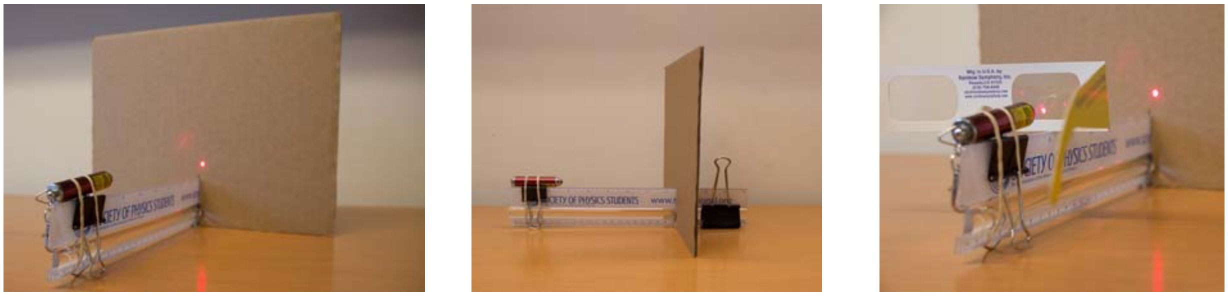
Introduction:

2014 is the International Year of Crystallography, which focuses on how we can use light to understand the structure of matter on the atomic level. This activity encourages students to think about how light can give us information about the structure of objects though diffraction patterns.
Be careful: This activity involves lasers. Be sure to explain the dangers of lasers and that improper use will result in the materials being taken away.

Note: We strongly recommended doing the pencil diffraction activity with students before doing this activity. Also, if students are not well versed in math, consider working through the calculations as a class using the averages of the values measured using worksheet v2. If the students are capable of doing the math, use worksheet v3.

Procedure:

1. Distribute the materials and help the students assemble the optics track as shown below. If your time is limited, pre-assemble the tracks.

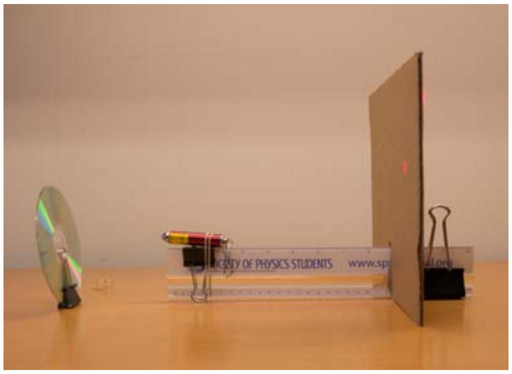


An assembled optics track.

2. Have the students complete section 1 of the worksheet. You can guide them through it step-by-step using the steps below, or have them complete all of the questions in small groups and then discuss the results as a class.
3. Have each group shine a laser through a lens on the diffraction glasses onto the cardboard screen. *What do you see? Does that look like something we looked at earlier?* Have students make a prediction about the structure of the "lenses" in the diffraction glasses based what they saw with the pencils and simulations. If necessary, talk them through coming to the realization that the diffraction glasses have really long, thin grooves running up and down through the lens, like multiple slits.
4. *Measure the distance between the brightest dot and the dot next to it. Also note the location of the diffraction grating and cardboard screen on the ruler.* Explain that we want to know this information so that we can calculate the spacing of the grooves in the lenses. In addition, show them that the wavelength of the laser, which they also need to know for the calculation, is printed on the laser or the cardboard insert. (**Note**: The red lasers included in the SOCK do not have the wavelength printed on them, it is printed on the package insert, and is listed as 630-680nm. This large range is not ideal for this activity. We suggest that you have students use the estimate of 650nm and then discuss the error that could result from this assumption.)
5. *Take some time to solve for the diffraction grating spacing by following the steps in the worksheet.* The spacing is 2μm.

6. Hold up the sheet of linear gratings. Shine the laser through each one and be sure to mention the line spacing for each group. *What is the relationship between line spacing and laser dot spread?*
7. Have the students complete section 2 of the worksheet.

8. Re-adjust the optics track so the screen is behind the laser. Mount the CD into a binder clip and put it at the end of the ruler.



The optics track reassembled for section 2.

9. *Take some time to shine the laser at the CD and look at the pattern that is reflected on the screen. What does this tell us about the structure of a CD? Does the pattern change with the orientation of the CD? Compare the pattern from the CD with the pattern from the diffraction glasses. Which pattern is larger? What does that tell you about the line spacing between the two?*
10. Have the students complete sections 3 and 4 of the worksheet. You can guide them through it step-by-step using the steps below, or have them complete all of the questions in small groups and then discuss the results as a class.
11. *While shining the laser on the CD, measure the distance between the brightest dot on the screen and one of the dots on either side.*
12. *Take some time to solve for the spacing on the CD by following the steps in the worksheet.*
13. Collect the calculated values. The average slit separation for a CD is roughly 1.5μm. *Compare the known value with the calculated values. How close are they? Why might they be different?*

Closing:

Crystallographers study the diffraction patterns created by different materials to understand their structure. However, they don't use red lasers; they use X-ray sources. X-rays have a very short wavelength. That wavelength is on scale with the width of an atom. We can use a red laser with the diffraction glasses and CDs because their structures are much bigger. If we tried to use X-rays on the CD or the diffraction glasses, the light would pass right through (not to mention we can't see X-rays)!

Crystallography—Structure matters

Expected Time: 20 min
Grade Level: All

Objective: Students will be able to…

1. Predict the diffraction pattern of a sample object based on its physical structure

Materials:

1. Hexagonal diffraction pattern printout
2. Square diffraction pattern printout
3. Bubble wrap
4. Diamond molecular structure kit
5. Red laser

Introduction:

This activity expands on the diffraction pattern activity to show how, even though some materials are made of the same elements, their structure can differ. This can result in different physical characteristics.

Procedure:

1. Distribute pieces of bubble wrap to the students. *Look at the bubble wrap for a minute. Do you see any repeating shapes or patterns?*
2. Crystallographers define a "unit-cell" as the smallest configuration that repeats itself in a crystal. *Do you see a repeating shape that could be called a unit-cell? If the shape/pattern you see goes up/down or left/right through the sheet, does it repeat itself if you move over by one row or column? If the shape/pattern is diagonal, does it repeat itself across the other diagonal?*
3. *Bubble wrap is an example of a hexagonal crystal structure. Its unit-cell, a hexagon, is the most efficient method for arranging circles and spheres.*
4. *What do you think the diffraction pattern would be for this material?* After collecting a few answers, shine a laser through the hexagonal diffraction slide. You will need to shine it on a wall across the room to spread the pattern out enough for a clear pattern to be visible.
5. *Bubble wrap is a good representation of the structure of graphene, which is a one-layer thick sheet of carbon atoms. If you stack sheets up bubble wrap on top of each other, you create graphite. Try stacking sheets of bubble wrap on top of each other, so the bubbles of one sheet touches the smooth side of the other. Slide the two across each other. Is it smooth? Can you see any other properties of this material?*
6. From the molecular structure kit, distribute five carbon atoms and four bonds to each group. *What shape can you make that uses up all of the atoms and bonds, stands up, and is symmetric? If you drop the shape on the ground, does it always stand up?*
7. The shape is a tetrahedron, also known as a triangle pyramid. *Gently press down on the tetrahedron. Does it feel rigid?*

8. Collect all of the shapes from the group and bring them to the front. *How can we stack these shapes to make another tetrahedron?* You may need to add in or remove some atoms or bonds to make the structure at right.

9. When the structure is complete, hold it up for everyone to see. Change its axis so they can see that it is symmetric. *What do you think the diffraction pattern of diamond is?*
10. *Diamond has a special pattern called a diamond lattice. However, it is very similar to the pattern in the square diffraction grating.* Shine the laser through it and show your students what that pattern looks like.
11. *Diamond and graphite are both made of the same thing (carbon atoms), but they have different structure, as we can see from the example and from their difficult diffraction patterns. To recap, what are the differences between the diamond and graphite structures? How do you think those differences affect their properties?*

Excited gases: Light as a tool for identifying gases (supplemental activity)

Expected Time: 20 min
Grade Level: All

Objective: Students will be able to…

1. Understand that gases give off unique light signatures
2. Articulate how this information is useful to scientists

Materials:

1. Discharge lamp (not provided)
2. Various gas tubes (not provided, Hydrogen, Helium, and Neon are recommended)
3. Diffraction glasses (1 per student)

Introduction:

Looking at the spectra of various gases is a useful way of determining the chemical makeup of an object. Astronomers use this technique to identify the makeup of stars. If they know what kinds of elements are in a star, they know something about the star's temperature, size, and lifetime.

Procedure:

1. Turn off the lights in the room and distribute the diffraction glasses.
2. Ask the students if they have ever seen neon signs before. If some have, follow up by asking what color the signs were.
3. Place the neon gas tube in the discharge lamp and turn it on. Have the students look at the neon without diffraction glasses. Ask them what color the neon gas is. Then, have the students put on their diffraction glasses and look at the gas again. Follow up by asking what other colors they see.
4. Repeat this procedure for other gases.

Explanation:

Every gas has its own fingerprint—called a spectrum—of light that it gives off when excited. Notice how the colors are in distinct bands. These patterns of light are always the same for a particular type of gas—whether the gas is in street signs, gas tubes, even in outer space. Astronomers look at stars through diffraction gratings to determine what elements are inside of a star. Knowing what elements are in a star can tell us about the star. The presence of certain elements means a star is old and cool, while other elements mean a star is young and hot.