TRAVELING OUTREACH DUFFLE BAG KIT MANUAL

DEVELOPED BY:

CENTER FOR INTEGRATED ACCESS NETWORKS

ENGINEERING RESEARCH CENTER

VERSION 1 – OCTOBER 2013

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Contents of Duffle Bag Kit

New Items in Duffle Bag

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- Diffraction Grating Glasses
- Hermograph Spectrum Viewers
- Glow-in-the-Dark Shutter Shading Glasses
- Human Eye Model
- Lava Rocks
- Nanosecond Bar
- Polarizing Filters
- Red Laser Pointers
- Violet Laser Pointers
- Aluminum Foil
- X-Acto knife
- Bright Flashlight
- Bright Fake Flowers
- Ball with Container
- Pringles Tube
- Plastic Mirror (2.5 in x 3.5 in.)
- Rolling Duffel Bag

Previous Items in Backpack

- 5 Rulers
- 5 Protractors
- 3 Rolls of Masking Tape
- 9 Mirrors in Plastic Cases
- 1 Pair of Scissors
- 3 Laser Markers (2 AAA batteries per marker)
- 1 Spool of Red Thread
- 1 Mini Fiber Optic Light (1 extra L1154 battery)
- 1 Mirage Kit
- 1 Solar Kit
- 1 Laser Radio Kit (2 AA batteries)
- 1 Fesnel Lens
- Mirage/Pig Demo

Short Explanation of New Contents Included in Kit

Self-Contained Demonstrations (Nothing Else Needed)

- Animation Praxinoscope – use to discuss early technology vs. new technology, compare to tv today, can have the kids draw their own animations
- Shrinking Coin Bank – use as a demonstration of reflection and how light works
- USB microscopes – use to demonstrate the variety of ways that optics can be used in a variety of sciences (i.e. this can be used for microscopic sciences)
- Oximeter – use to demonstrate the variety of ways that optics can be used in a variety of sciences (i.e. this can be used for medical sciences)
- Orion GoScope II 70mm Refractor Telescope – use to demonstrate the variety of ways that optics can be used in a variety of sciences (i.e. this can be used for macroscopic sciences)
- Paper towel rolls – use to do the 'Hole in the Hand' demo (hold the roll up to one eye with both eyes open, place the hand in front of your other eye at the end of the roll so you can see it and slowly move it forward until you realize there's a hole in your hand)
- Mirage/Pig Demo – demonstrates the ideas of transference of information, reflection of light, and light properties

Other Demonstration Tools

- Diffraction Grating Glasses – Giveaway, each bag contains 300 to be given out to children throughout the year
- Hermograph Spectrum Viewers – can be used in combination with the diffraction grating glasses to show various elemental makeup of light sources (can be used to discuss how we know what stars are made up of)
- Glow-in-the-Dark Shutter Shading Glasses – for kids to wear, then turn off lights so they can see the glow-in-the-dark property and talk about phosphorescence and absorption of photons
- Human Eye Model – use to explain the way that we see light, can be passed around, specifically point out the retina and the way that singles travel through the eye to the brain
- Lava Rocks – to be used with the Fresnel lens to show how by changing the path of light you can concentrate it and use it to affect something else (i.e. melt the lava rocks)
- Nanosecond Bar – can be used to talk about the speed of light
- Polarizing Filters – talk about everyday technology such as sunglasses and how we can filter light in certain ways
- Red Laser Pointers – general use (can be used with pringles pinhole demo, shrinking coin bank, and anything else you can think of)
- Violet Laser Pointers – general use (can be used with pringles pinhole demo, shrinking coin bank, and anything else you can think of)
- Aluminum Foil – for use with various demos
- X-Acto knife – for use with various demos
- Bright Flashlight – for use with various demos
- Bright Fake Flowers – to be used with the Pringles Pinhole Exploratorium demo
- Ball with Container – to be used with the Fiber Optic Class demo
- Plastic Mirror (2.5 in x 3.5 in.) – to be used with various demos

Rolling Duffel Bag – to store items. Small backpack can be used to carry only a number of these items.

Breakdown of Demonstration Instructions

Demonstration Instructions with all Materials in Duffle Bag Kit

- The Fiber Optic Cable Class - **CIAN**
- Pictures from Light – **Exploratorium**
- Hit the Target – **SPIE, OSA, AURA & NOAO**

Self-Contained Demonstration Tools without Instructions in Manual

- Animation Praxinoscope
- Shrinking Coin Bank
- USB microscopes
- Oximeter
- Orion GoScope II 70mm Refractor Telescope
- Paper towel rolls
- Mirage/Pig Demo

Demonstration Instructions With Consumable Items Needed

- Pringles Pinhole – **Exploratorium**
  - Pringles can
- Up Periscope! – **Exploratorium**
  - Two 1-quart milk cartons, masking tape
- Reflecting Rainbows – **Exploratorium**
  - 1 CD, piece of white paper
- What is Light? – **CIAN-ROKET**
  - 1 CD, an empty cereal box
- Tomatoes and Rainbows-What Color Is It? – **Outreach Magic Workshop**
  - Small tomatoe, plum, or tangerine (small colored candies also work); two different colored LEDs (or more) or a flashlight covered with blue, green, or red plastic film
- The Disappearing Beaker – **Outreach Magic Workshop**
  - Two Pyrex beakers (see activity for specific details), Vegetable oil
- The Magic Box – **Outreach Magic Workshop**
  - Cardboard box (tissue box), knife or chopstick for added effect
- Polarized Light Art – **Outreach Magic Workshop**
  - Cellophane tape, clear plastic (transparency film), glue sticks

Demonstration Instructions Needing Other Materials (More Time to Prepare)

- The Amazing Bedazzled Kaleidoscope – **Outreach Magic Workshop**
- Amazing Jello – **Outreach Magic Workshop** (requires preemptive preparation, see activity for details)
- The Misbehaving Lens – **Outreach Magic Workshop**
- Light you Can't See – **Outreach Magic Workshop**
- Polarizing Filter Demo Kit – **Educational Innovations**

Breakdown of Demonstration Instructions by Time

Note: Depending on who is giving the above demonstrations that may take more or less time than stated above. If able, take some time before doing the demos for students and practice it, add in time for questions.

Demonstrations that take 5 to 15 minutes

- Animation Praxinoscope
- Shrinking Coin Bank
- USB microscopes
- Oximeter
- Paper towel rolls
- Reflecting Rainbows – **Exploratorium**
- Tomatoes and Rainbows-What Color Is It? – **Outreach Magic Workshop**
- Mirage/Pig Demo

Demonstrations that take 15 to 30 minutes

- Pictures from Light – **Exploratorium**
- Pringles Pinhole – **Exploratorium**
- Up Periscope! – **Exploratorium**
- The Amazing Bedazzled Kaleidoscope – **Outreach Magic Workshop**
- The Disappearing Beaker – **Outreach Magic Workshop**
- Amazing Jello – **Outreach Magic Workshop** (requires preemptive preparation, see activity for details)
- The Magic Box – **Outreach Magic Workshop**
- Polarized Light Art – **Outreach Magic Workshop**

Demonstrations that take 30 to 45 minutes

- Hit the Target – **SPIE, OSA, AURA & NOAO**
- Orion GoScope II 70mm Refractor Telescope
- The Misbehaving Lens – **Outreach Magic Workshop**
- Light you Can't See – **Outreach Magic Workshop**
- Polarizing Filter Demo Kit – **Educational Innovations**

Demonstrations that take 30 minutes to 1 hour

- The Fiber Optic Cable Class – **CIAN**
- What is Light? – **CIAN-ROKET**

Demonstrations that can be Printed, Distributed, and Taken Home by Students

- Pringles Pinhole – **Exploratorium**
- Up Periscope! – **Exploratorium**
- Reflecting Rainbows – **Exploratorium**
- Pictures from Light – **Exploratorium**

Breakdown of Demonstration Instructions by Age Group

Note: Age group can be adjusted one way or another depending on the level of explanation. These separations are suggestions.

Demonstrations for Elementary Students

- Pictures from Light
- Orion GoScope II 70mm Refractor Telescope
- What is Light?
- Tomatoes and Rainbows-What Color Is It?

Demonstrations for Middle School Students

- The Fiber Optic Cable Class
- Pictures from Light
- Hit the Target
- Orion GoScope II 70mm Refractor Telescope
- Pringles Pinhole
- Up Periscope!
- What is Light?
- Tomatoes and Rainbows-What Color Is It?
- The Misbehaving Lens
- The Magic Box
- Polarized Light Art
- Polarizing Filter Demo Kit

Demonstrations for High School Students

- The Fiber Optic Cable Class
- Hit the Target
- Orion GoScope II 70mm Refractor Telescope
- Pringles Pinhole
- Up Periscope!
- The Misbehaving Lens
- The Magic Box
- Polarized Light Art
- Polarizing Filter Demo Kit

Demonstrations for any Age

- Animation Praxinoscope
- Shrinking Coin Bank
- USB microscopes
- Oximeter
- Paper towel rolls
- Mirage/Pig Demo
- Reflecting Rainbows
- The Disappearing Beaker
- The Amazing Bedazzled Kaleidoscope
- Amazing Jello
- Light you Can’t See

DEMONSTRATION INSTRUCTIONS

THE FIBER OPTIC CABLE CLASS

Developed by CIAN Education Staff, 10/8/2013

The Fiber Optic Cable Class

Developed by CIAN Education Staff, 10/8/2013

Overview

This activity is an interactive "out-of-the-seat" demo that allows the students to become involved in learning about fiber optic cables by imitating the way that one basically functions. While enjoying the physicality of the demo the children will pick up basic details of light, reflection, optical properties, and applications to technology. An emphasis should be placed on asking direct questions to the children about how these concepts can influence technology and our world to reinforce the concepts that they are learning about.

Students Will Learn…

Students will learn the basics of how fiber optics work along with the basics of the difference between photons and electrons, the speed of light, total internal reflection, and more.

Questions to Answer

- What is light?
- What can we do with light?
- How can light be used in technology?
- What is reflection? What is total internal reflection?
- How does this apply to the real world?

What You Need

- Orange Ball
- Note from the Teacher (or other fun thing to put in the ball, i.e. a small toy)
- Multiple Mirrors
- Laser pointer
- String or preferably a length of fiber optic cable (string is included in the backpack)

Time Estimate: 45 minutes to 1 hour
Grade Level: 3-12 (depending on explanation of concepts)

Getting Ready

Before the class have the teacher prepare a note or a fun little item to hide in the orange ball. The students will stand for the demo and randomly arrange themselves about the room. After tossing the ball a path will be marked with string or fiber optic cable, mirrors will be passed out, and a laser pointer will be given to the starting student while the last student has a target.

Demo Walkthrough

1. Start with everyone standing around the room randomly. Tell them that they have to get the orange ball from one side of the room (pick a student) to the other, as fast as they can, while still getting the ball to every student.
2. Track the path the students take to throw the ball by handing the students a part of a long string or, if available, a part of the fiber optic cable.
3. Discuss electrons. Ask about what they know of that has wires with electrons moving through it. After some examples, use one of your own (maybe TV) and talk about how the electrons moving through the wires bring us information, the images on the TV.
4. Now that the ball has gotten to the last student tell that student to look at the ball and take out the note/toy that is hidden inside of it and read or describe what it is to the rest of the class. Ask the students what they think the orange ball is like (discuss how it is like an electron and they are the wire).
5. Have the students set the string/cable on the floor at their feet so that they can see the path they took with the ball. Hand out mirrors to everyone in the middle, a laser pointer to the starting person, and a target to the last person.
6. Tell the students that now they have to recreate the path the ball took, but with the laser pointer using mirrors to reflect the light to the target (WARNING: Do not shine lasers into eyes. This activity is not appropriate for young children that cannot follow this instruction, if the students cannot follow this instruction the activity will need to be ended and an alternative taken)
7. Let them work to get the light from one side of the other. At the end, ask what takes longer to get from one side to the other, the ball or the light? (the ball, because it has to go to each person every time, whereas the laser light is continuous so once the path is established it is as fast as the speed of light)
8. Discuss how this might be used in the real world (if light can move faster than electrons, couldn't we transfer information faster?)
9. (if you have the fiber optic cable) Have the students pick it up with the first person using the laser to shine the light through the fiber optic cable showing that it comes out the other side.
10. Talk about total internal reflection and how this technology is being used to make the internet even faster along with many other things.

PICTURES FROM LIGHT

Developed by Exploratorium

http://www.exploratorium.edu/science_explorer/pictures_from_light.html

Pictures from Light

With a lens, you can bend light to make pictures of the world.

What do I need?

- lens-like the one in a magnifying glass or one from a disposable camera
- room that you can make very dark
- light source-like a TV set or a brightly lit window
- sheet of white paper

What do I do?

1 Look through your lens at these words or at your fingertip. Do things look bigger through your lens? If they do, your lens is a magnifying lens. It will work for this experiment.

2 Go into a room that has just one source of light. On a sunny day, a window works just fine. (Turn off any electric lights in the room.) At night, you can turn on your TV set and use it as a light source.

You're going to use your lens to make a picture of the light source. So you want a light source that will make an interesting picture. A picture of an ordinary lightbulb is just a round spot, which is pretty boring.

3 Stand a few feet away from your light source. Hold your lens up so that light can shine through it. Hold the piece of paper on the other side of the lens so that light shines through the lens and onto the paper.

The paper is your screen-like the screen in a movie theater. The paper screen will reflect a picture made of light so that you can see it.

4 Start with the lens up close to the paper, and slowly move it away from the paper and toward the light source. Watch the pattern of light on the paper. When the lens is the right distance from the paper, you'll see a picture of the light source. The picture will be upside down and backward.

5 If you don't see a picture right away, keep trying. Try standing closer to the light source. Or try moving the lens farther from the paper. It may take some experimenting, but sooner or later you'll get a picture.

Wow! I Didn't Know That!

When you use your lens to make a picture of something that's brightly lit, you are doing the same thing that a movie projector does. In a movie projector, a light shines through a transparent picture, then through a lens. The lens takes the light from the picture and makes a big picture on the movie screen.

What's Going On?

Warning

You may already know that you can use a lens to focus sunlight into a very bright circle. That circle can be hot enough to start a fire. For many kids, playing with a lens outdoors can be like playing with matches. Take appropriate precautions.

If you take a lens outside and use it to focus a circle of sunlight, DON'T stare at the bright spot. That spot of light is an image of the sun. You can hurt your eyes by staring at it, just as you can hurt your eyes by staring at the sun.

Return to The Science Explorer Exploratorium-At-Home Book

Published by Owl Books,
Henry Holt & Company, New York,
1996 & 1997

ISBN 0-B050-4536 & ISBN 0-8050-4537-6,

$12.95 each

HIT THE TARGET

The International Society for Optical Engineering
The Optical Society of America
the Association of Universities for Research in Astronomy, Inc.

Hit the Target

Overview
This is the culminating activity, requiring students to use all the practiced skills from the previous activities. An emphasis should be placed on making accurate measurements and predictions of angles, and in following the rules of the challenge.

Students Will Learn…
- How to use the law of reflection to design an "obstacle course" for a laser using multiple mirrors to direct the laser beam to a specific target.

What You Need
For each group of 2-3 students:
- ☐ 3 mirrors (3"x3"), mounted in plastic holders
- ☐ 1 laser
- ☐ 3 paper or plastic protractors
- ☐ String
- ☐ Roll of masking tape
- ☐ Copy of paper target
- ☐ 1 yardstick or ruler
- ☐ Copy of "STUDENT HANDOUT: Hit the Target" (put Scorecard on the back side)

HINT: The ½ bullseye design target requires that students take the planar nature of the law of reflection into account. It is more difficult than the vertical stripes target.

Getting Ready
1. If possible, recruit an assistant or two to help you manage this activity. It is likely that multiple groups will have their setups ready at approximately the same time, and if they are waiting on you, the students will be tempted to turn on the laser while you aren't looking.

2. Make sure there is sufficient space in which the groups will work, either on the floor or on a large, flat surface.

GO: Hit the Target
1. Remind students of laser safety considerations. With multiple lasers being used throughout the room, it is especially careful that students be aware of where their laser beam is likely to go.

2. Describe the challenge to the students. Remind them that the challenge includes designing the setup WHILE THE LASER IS TURNED OFF. They should NOT turn the laser on at any point before they have called the instructor over to inspect the setup.

3. Pass out the "STUDENT HANDOUT: Hit the Target" to each group.

4. Set up a kitchen timer or other alarm to notify students when a round is completed.

5. Decide in advance how you will award points if the laser beam appears directly on a boundary between two regions of the target. Tally points on the board or on chart paper.

Going Further

1. Do not give the students the laser in advance, but only perhaps the box. Bring the laser to each group as they are ready. The group has an additional one minute to align the laser.

2. An advanced challenge could involve incorporating the 3-dimensional nature of the law of reflection. Students would place the laser, for example, on a table or desk with the mirrors set up so that the laser beam hits a target on or near the floor.

3. Create new, more challenging targets for students to use.

4. Reduce the amount of time given for each round or the number of tries allowed per round.

HINT: As a reminder, this activity will be particularly difficult if students are finding that the mirrors are not perpendicular to the surface. Carpeted surfaces are especially bad for this activity. Some suggestions to improve the situation are:

- Use paper or some other "shim" to prop up one side of the mirror holder, much as you might do with a wobbly table.
- Rotate the mirror by 90°, so that the mirror holder is on the side (vertical).
- Use two mirror holders per mirror, with the holders placed vertical and the mirror bottom not touching the surface.

STUDENT HANDOUT: Hit the Target

Now that you have had practice measuring and using the law of reflection, you can apply what you've learned to hit a target with a laser by strategically placing mirrors.

Your Challenge
Round 1- Hit the target using one mirror
Round 2- Hit the target using two mirrors
Round 3- Hit the target using three mirrors

What You Need
(Note: you do not have to use all provided materials)

- ❑ 3 mirrors (3"x3"), mounted in plastic holders
- ❑ 1 laser
- ❑ 3 protractors
- ❑ String
- ❑ 1 roll of masking tape
- ❑ 1 target
- ❑ 1 yardstick or ruler

Rules

1. **Most importantly: the laser <u>must</u> be turned off while you are moving the mirrors.**

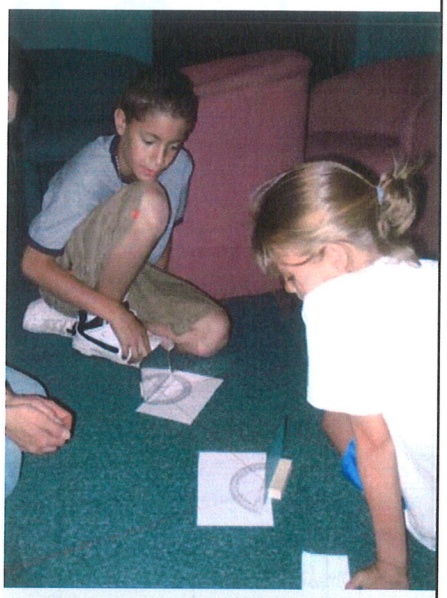
2. The target must be placed 4 feet away from the laser and not in its direct path.

3. Mirrors must be 1-4 feet away from each other and the laser.

4. Once the laser position is set, it cannot be moved. Tape the laser to the floor.

5. Call your instructor over when you are ready to test your setup. He or she will turn on the laser. You will have three tries to hit the target. After each attempt the laser will be turned off so you can make adjustments. Record your score after each attempt.

6. Repeat with one additional mirror for each round. Each round will last approximately 20 minutes. The team with the most points at the end of Round 3 is the <u>Master of Reflections</u>.



Questions for each group to ponder:
- How will you keep track of the laser's path?
- How will you make sure the path you mark is straight?
- Will you decide on the mirror positions first or decide on the path of the laser first?
- How will you use the protractors to predict the path of your reflections?
- Are there other methods of checking that your setup will work?
- How will you manage your time to get in 3 accurate attempts for each round?

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Hit the Target Scorecard

You get three attempts to hit the target in each round. Record your scores in the table below.

Round 1 : One mirror

Attempt	Score
1	
2	
3	

Round 1 Total : _____

Round 2 : Two mirrors

Attempt	Score
1	
2	
3	

Round 2 Total : _____

Round 3 : Three mirrors

Attempt	Score
1	
2	
3	

Round 3 Total : _____ **Grand Total:** _____

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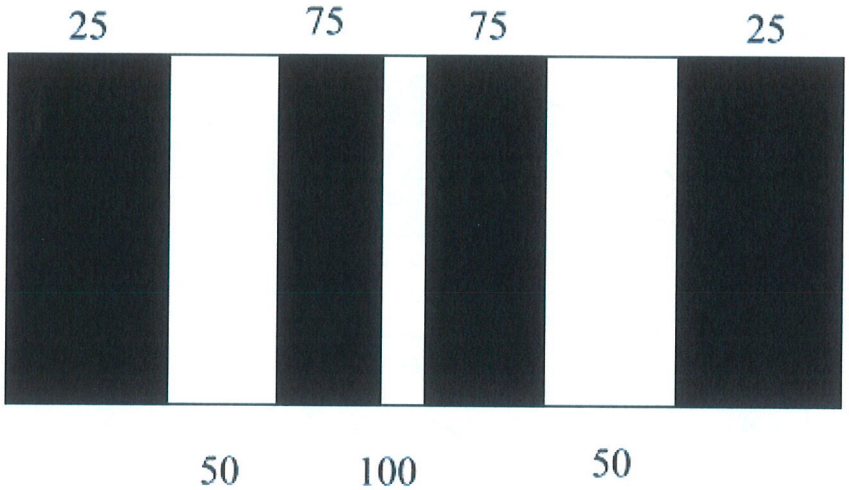
Targets for the *Hit the Target* Activity



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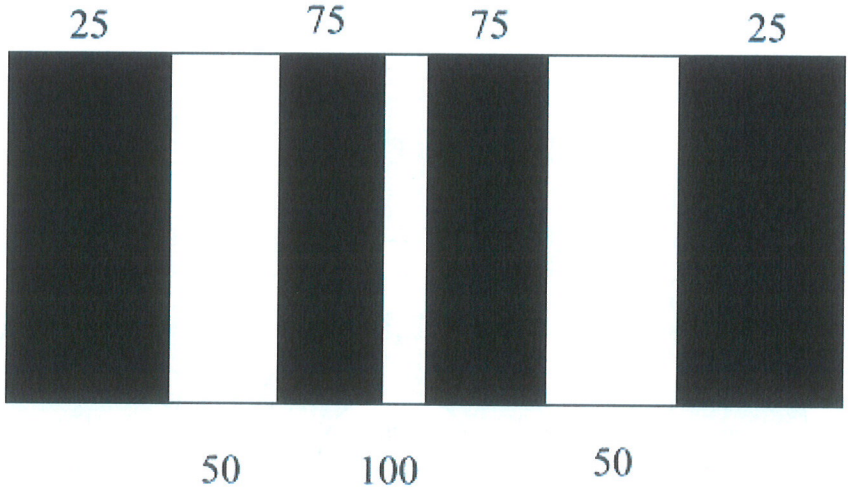

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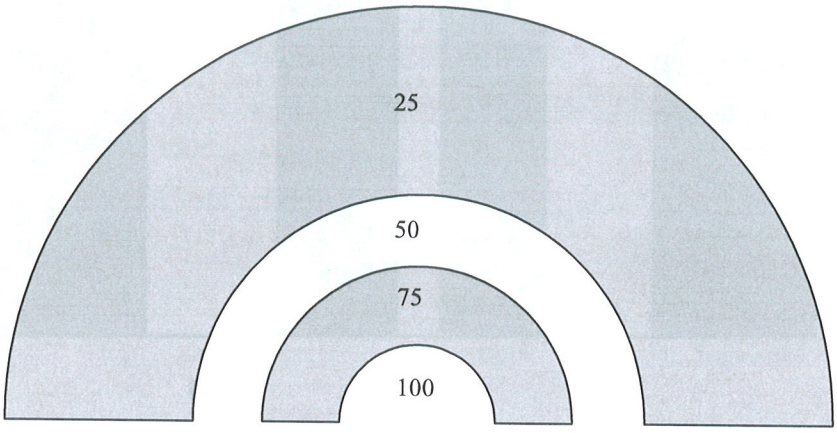

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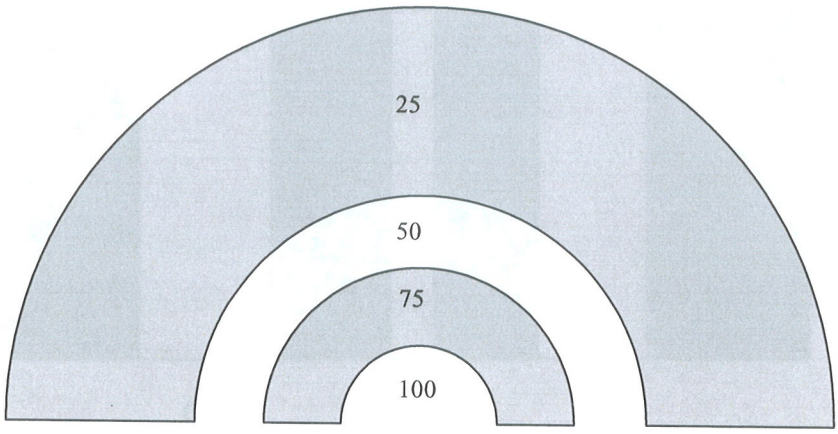

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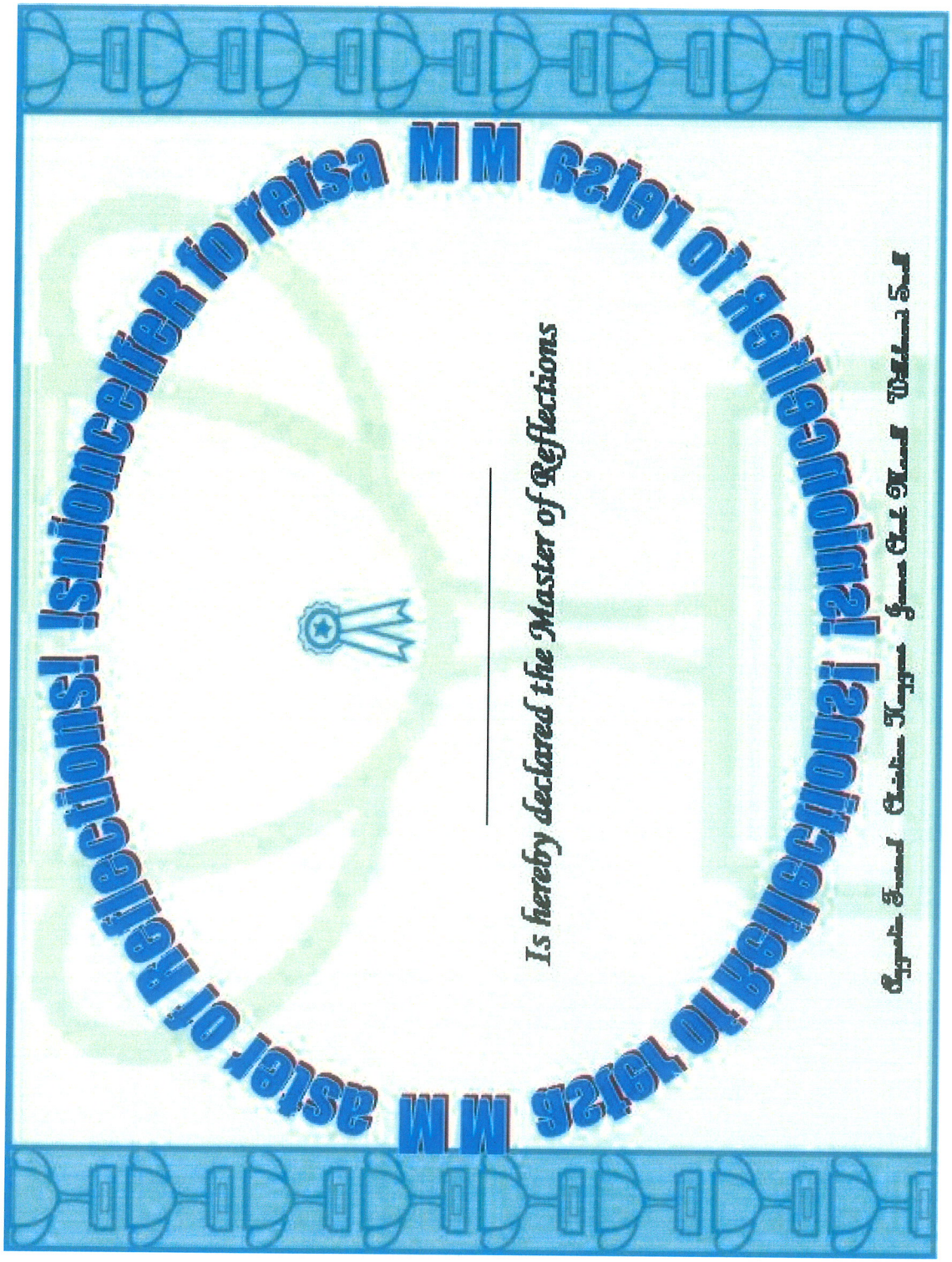

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PRINGLES PINHOLE

Exploratorium

http://www.exploratorium.edu/science_explorer/pringles_pinhole.html

Pringles® Pinhole

Recycle a potato chip can into a simple camera!

What do I need?

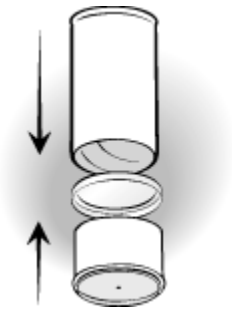
- empty Pringles® chip can
- marker
- ruler
- X-Acto knife or utility knife (ask a grown-up to help you cut)
- thumbtack or pushpin
- masking tape
- aluminum foil
- scissors (if you want)
- bright sunny day

What do I do?

1 Take the plastic lid off the Pringles® can and wipe out the inside. (Save the lid!)

2 Draw a line with the marker all the way around the can, about 2 inches up from the bottom. Have a grown-up cut along that line so the tube is in two pieces.

3 The shorter bottom piece has a metal end. With the thumbtack, make a hole in the center of the metal.



4 We're going to use the plastic lid as a screen. If your lid is clear, you may need to apply a piece of wax paper, white tissue paper, or vellum to the lid to act as a translucent screen. Put the plastic lid onto the shorter piece. Put the longer piece back on top. Tape all the pieces together.

5 To keep light out of the tube, use a piece of aluminum foil that's about 1 foot long. Tape one end of the foil to the tube. Wrap the foil all the way around the tube twice, then tape the loose edge of the foil closed. If you have extra foil at the top, just tuck it neatly inside the tube.

6 Go outside on a sunny day. Close one eye and hold the tube up to your other eye. You want the inside of the tube to be as dark as possible-so cup your hands around the opening of the tube if you need to.

Look around your yard through the tube. The lid makes a screen that shows you upside-down color pictures!

7 Hold your hand below the tube and move it very slowly upward. Your hand is moving up, but you'll see its shadow move down the screen!

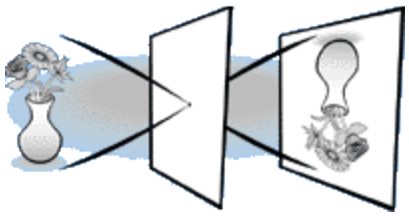
What's Going On?

How does a hole in the bottom of a Pringles® can make a picture of the world?

The hole doesn't make the picture. The image of the world is always there. All the hole does is make it possible for you to see it.

Suppose you point your Pringles® Pinhole at a brightly lit bouquet of flowers. Light reflects off the red rose, the blue iris, the white daisy, and the green leaves. If you hold a piece of white paper near the bouquet, some of that reflected light will shine on the paper-but it won't look like anything. That's because light bouncing off the red rose ends up overlapping with light bouncing off the blue iris, the white daisy, and the green leaves. There are many images of the bouquet on the paper-but they overlap with one another, and the colors all blend together, making a jumble of light.

The hole isolates a small part of the light, sorting a single image from the jumble. Only a few of the light rays reflecting off each point on the rose are traveling in a direction that will let them pass through the hole. The same is true for light bouncing off all the other flowers in the bouquet. On the other side of the hole, these light rays reveal an image of the bouquet.



Wow! I Didn't Know That!

You've made a camera! This kind of camera is called a camera obscura-which is Latin for "dark chamber." The first camera obscuras were small rooms that were completely dark except for a tiny hole in a wall that let in a dot of sunlight. People in the room saw an image of the trees and sky on the wall opposite the hole-and were amazed when the image disappeared at sunset!

The Home Scientists in the Graff family improved their Pringles® Pinhole by using a foam soda can holder as an eyepiece. It made the inside of the tube dark, and was easier to use for people who wear glasses.

Return to The Science Explorer Exploratorium-At-Home Book

This and dozens of other cool activities are included in the Exploratorium's Science Explorer books, available for purchase from our online store.

About the Books...

Published by Owl Books,
Henry Holt & Company, New York,
1996 & 1997

ISBN 0-B050-4536 & ISBN 0-8050-4537-6,

$12.95 each

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exploratorium

UP PERISCOPE!

Exploratorium

http://www.exploratorium.edu/science_explorer/periscope.html

Up Periscope!

Build a mirrored tube that lets you see around corners and over walls.

What do I need?

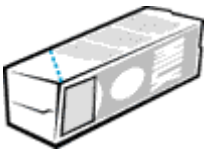
- Two 1-quart milk cartons
- Two small pocket mirrors (flat, square ones work best)
- Utility knife or X-Acto knife
- Ruler
- Pencil or pen
- Masking tape

DANGER!
An X-Acto knife is very, very sharp. Have a grown-up do all the cutting in this activity.

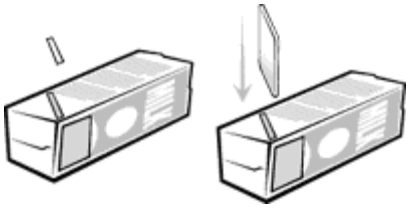
What do I do?

1 Use the knife to cut around the top of each milk carton, removing the peaked "roof."

2 Cut a hole at the bottom of the front of one milk carton. Leave about 1/4 inch of carton on each side of the hole.



3 Put the carton on its side and turn it so the hole you just cut is facing to your right. On the side that's facing up, measure 2 3/4 inches up the left edge of the carton, and use the pencil to make a mark there. Now, use your ruler to draw a diagonal line from the bottom right corner to the mark you made.



4 Starting at the bottom right corner, cut on that line. Don't cut all the way to the left edge of the carton-just make the cut as long as one side of your mirror. If your mirror is thick, widen the cut to fit.

5 Slide the mirror through the slot so the reflecting side faces the hole in the front of the carton. Tape the mirror loosely in place.

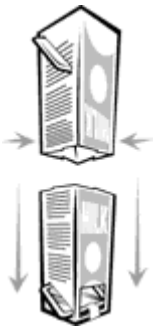
6 Hold the carton up to your eye and look through the hole that you cut. You should see your ceiling through the top of the carton. If what you see looks tilted, adjust the mirror and tape it again.

7 Repeat steps 2 through 6 with the second milk carton.

Wow! I Didn't Know That!

Periscope comes from two Greek words, **peri**, meaning "around," and**scopus**, "to look." A periscope lets you look around walls, corners, or other obstacles. Sub-marines have periscopes so the sailors inside can see what's on the surface of the water, even if the ship itself is below the waves.

8 Stand one carton up on a table, with the hole facing you. Place the other carton upside-down, with the mirror on the top and the hole facing away from you.



9 Use your hand to pinch the open end of the upside-down carton just enough for it to slide into the other carton. Tape the two cartons together

10 Now you have a periscope! If you look through the bottom hole, you can see over fences that are taller than you. If you look through the top hole, you can see under tables. If you hold it sideways, you can see around corners.

What's Going On?

What kinds of mirrors can I use to make a periscope?

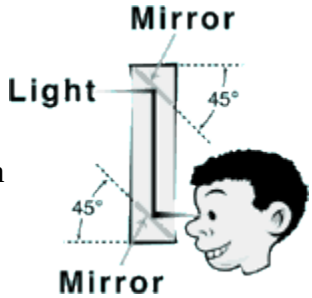
You need two small mirrors, but they don't have to be identical. If you have a rectangular mirror, or one with a handle, it's okay if part of it sticks out the side of the carton. If your mirror is round, like the mirror in a make-up compact, you may want to tape or glue it to a square of cardboard before inserting it into the slot in the milk carton. If you have a mirror with a magnifying side and a nonmagnifying side, have the nonmagnifying side facing the hole.

To make a periscope from a 1-quart milk carton, your mirrors must be smaller than 31/2 inches in at least one dimension. If the only mirrors you can find are larger than that, you can use half-gallon milk cartons instead.

What if I want to use half-gallon milk cartons or some other boxes?

When you are making a periscope, it's important to make sure that your mirror is positioned at a 45-degree angle. If you use a wider milk carton or some other box, just measure how wide your box is. Then measure that same distance up the side of the box and make a mark. The line between your mark and the opposite corner of the box will be at 45 degrees.

How does my periscope work?



Light always reflects away from a mirror at the same angle that it hits the mirror. In your periscope, light hits the top mirror at a 45-degree angle and reflects away at the same angle, which bounces it down to the bottom mirror. That reflected light hits the second mirror at a 45-degree angle and reflects away at the same angle, right into your eye.

Can I make a periscope with a really long tube?

You can make your peri- scope longer, but the longer the tube is, the smaller the image you'll see. Periscopes in tanks and submarines have magnifying lenses between the mirrors to make the reflected image bigger.

Return to The Science Explorer Exploratorium-At-Home Book

About the Books...

This and dozens of other cool activities are included in the Exploratorium's Science Explorer books, available for purchase from our online store.

Published by Owl Books,
Henry Holt & Company, New York,
1996 & 1997

ISBN 0-B050-4536 & ISBN 0-8050-4537-6,
$12.95 each

Reflecting Rainbows

Exploratorium

http://www.exploratorium.edu/science_explorer/reflecting_rainbows.html

Reflecting Rainbows

Decorate your white walls with rainbow colors!

What do I need?

- compact disc (also known as a CD) (If you don't own any CDs, you can buy an old one at a garage sale. Or ask at a record store if they will give you a CD that won't play.)
- sunshine (or a bright flashlight and a room that you can make dark)
- piece of white paper

What do I do?

1 Take the CD out of its case and take a look at the blank side (the side that doesn't have any printing on it). You'll see bands of shimmering color. Tilt the CD back and forth and the colors will shift and change.

2 Hold the CD in the sunshine. Or if it's a cloudy day, turn out the lights and shine your flashlight at the CD. Hold your piece of white paper so that the light reflecting off the CD shines onto the paper. The reflected light will make fabulous rainbow colors on your paper.

3 Tip the CD and see how that changes the reflections. Change the distance from the CD to the paper. What happens to the colors?

4 Take a close look at your CD. It's made of aluminum coated with plastic. The colors that you see on the CD are created by white light reflecting from ridges in the metal.

More things to do

When light reflects off or passes through something with many small ridges or

scratches, you often get rainbow colors and interesting patterns. These are called interference patterns. Here are several other ways you can see interference patterns.

- Squint at a distant bright light at night. You'll see starburst patterns around the light. If you look closely, you can see colors in the patterns. These patterns form when light bends around your eyelashes and imperfections in the layers that make up the lens of your eye. Tilt your head to one side while watching the pattern and notice that the pattern moves with you.
- In a dark room, look at a bright light (maybe a candle flame) through a nylon stocking, a silk scarf, a feather, or a tea strainer. The pattern that you see depends on what you look through. Move the thing you're looking through and notice that the pattern moves with it.
- Buy a set of "rainbow glasses" in a toy store or a science shop. Through these glasses, all lights look like rainbows. The glasses are made with diffraction gratings, clear plastic that is etched with many lines.

What's Going On?

Why does a CD reflect rainbow colors?

Like water drops in falling rain, the CD separates white light into all the colors that make it up. The colors you see reflecting from a CD are interference colors, like the shifting colors you see on a soap bubble or an oil slick.

You can think of light as as being made up of waves-like the waves in the ocean. When light waves reflect off the ridges on your CD, they overlap and interfere with each other. Sometimes the waves add together, making certain colors brighter, and sometimes they cancel each other, taking certain colors away.

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WHAT IS LIGHT?

CIAN ROKET Program

What is Light?

Lesson Template

Subject Area(s) Optical Science

Associated Unit Light, diffraction, and light waves

Lesson Title Diffraction of light (making a monochrometer)

Grade Level 5 (3-6)

Lesson # 1 of 1

Time Required 45-60mins (may require two class periods)

Summary: In this lesson students will learn that light travels in waves. Visible light is only a small part of the electromagnetic spectrum and each color of visible light is a different wavelength. This lesson can also be broken into smaller units should the instructor decide to spend more time teaching the electromagnetic spectrum, light wavelengths and diffraction.

Engineering Connection: Optical sciences and physics

Keywords: Wavelengths, diffraction, spectrum

Educational Standards

State science: S5-C3-PO1-3

State math: M05-S5C2-06

Learning Objectives

After this lesson, students should be able to:

- **Explain and define "diffraction" Explain that light travels in wavelengths, and each wavelength of visible light varies in length and this determines color. For example, a blue ray of light will have a wavelength of about 450 nanometers.**
- **Students will be able to reference a electromagnetic spectrum of visible light to show which colors correspond with wavelengths.**
- **Students will build a monochrometer to demonstrate the concept of diffraction.**

Introduction / Motivation: Students should be asked the question, "what is light?" They should be given about one minute to discuss what light is and then be ready to give an answer. If you use science journals or lab notebooks, students should write this question down, and then asked to write down their answers in their journals in addition to a verbal response. Explain that there are all kinds of light and all light travels in waves. Some waves are longer, and some are shorter. The shorter the wavelength, the more excited or powerful that wavelength will be, and the longer the wavelength the less excited and weaker the wavelength will be. However, not all light is visible (refer to the electromagnetic spectrum. Figure 1),

examples of invisible light is infrared and ultraviolet. So where in nature do we most often see many colors of light all at once (what do you often see when it rains)? Why do rainbows appear? How can we re-create a rainbow/spectrum of light?

Lesson Background & Concepts for Teachers: Different colors of visible light are of different wavelengths. Light can be diffracted (separated by wavelength/color) with a diffracting medium (i.e. CD, diffracting grade, prism). Light is only visible at a certain spot on the spectrum (see Figure 1). Each color has its own nanometer of wavelength, purple having the smallest number and red, the largest. Above and below these colors, light is no longer visible.

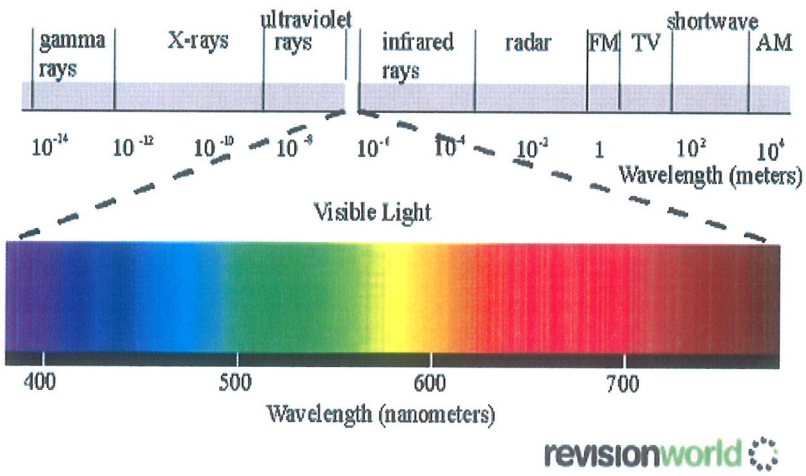

Figure 1

Vocabulary / Definitions

Word	Definition
Diffraction	**bending of waves:** the bending or spreading out of waves, e.g. of sound or light, as they pass around the edge of an obstacle or through a narrow aperture
Wavelength	**The distance between crests of a wave.** The wavelength determines the nature of the various forms of radiant energy that comprise the electromagnetic spectrum. The wavelength is the distance between crests. The higher the frequency, the shorter the wavelength.
Electromagnetic Spectrum	The entire range of wavelengths or frequencies of electromagnetic radiation extending from gamma rays to the longest radio waves and including visible light.

Associated Activities: Students will build a monochrometer to demonstrate how light breaks up into different wavelengths and colors.

This simple spectrometer can be built from a CD and a cereal box. Cut a 0.2mm wide slit on one side of the box and place the CD on the other side with about a 60 degree angle. Look down into the opening on the box.

Figure 2. structure of the CD spectroscope

Figure 3. cereal box spectroscope (arrow: the slit)

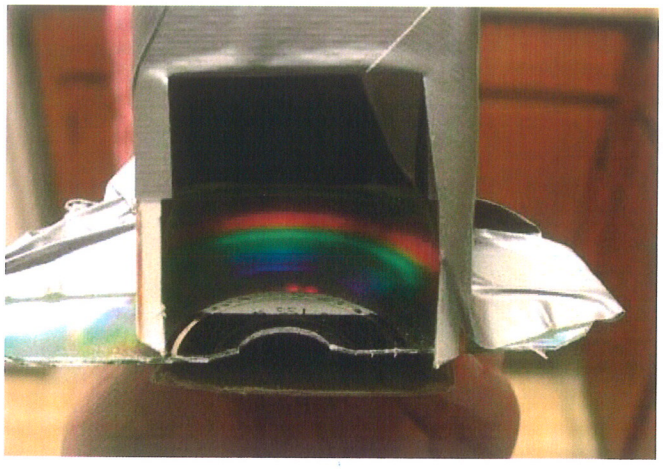

Figure 4. viewing the spectrum

Assessment: Students will be asked to demonstrate the concept of diffraction by building a monochrometer and explaining how it works. They will use different forms of light to observe the changes in the spectra. For example:

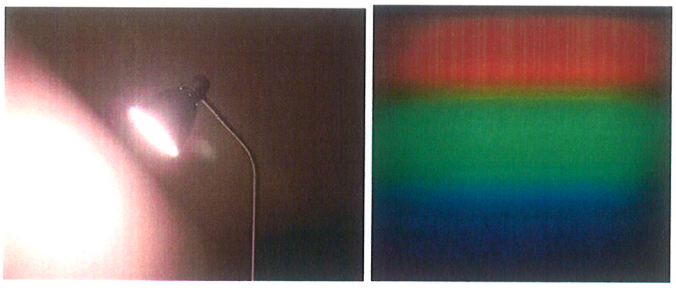

Figure 5. incandescent light

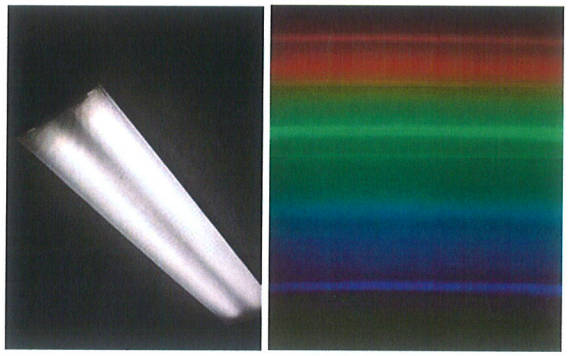

Figure 6. fluorescent light

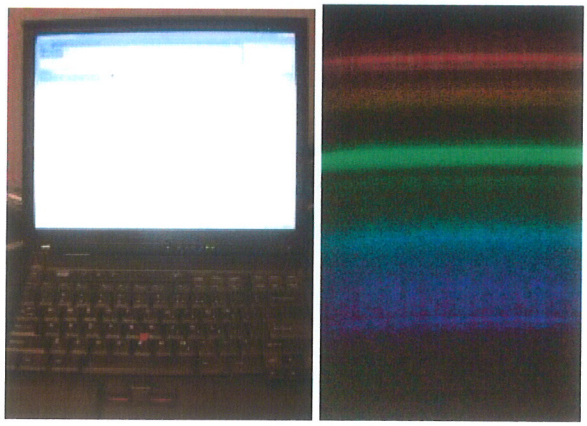

Figure 7. laptop display

Source: http://www.cs.cmu.edu/~zhuxj/astro/html/spectrometer.html

Supporting Program: CIAN-ROKET University of Arizona, College of Optical Sciences

Outreach Magic Workshop Packet

Including:

Tomatoes & Rainbows-What Color Is It?

The Amazing Bedazzled Kaleidoscope;

The Disappearing Beaker;

Amazing Jello;

The Misbehaving Lens;

The Magic Box;

Polarized Light Art;

Light You Can't See

Optics Magic: Easy Demonstrations from the PHOTON Projects

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Nancy Magnani
EASTCONN
Willimantic, CT, USA
nmagnani@eastconn.org

Make glass disappear! Turn a tomato into a plum! See a "solid" wall vanish before your eyes and more. It's all done with optics! These inquiry-based demonstrations in light and vision may be easily replicated with inexpensive, commonly found supplies. This hands-on workshop is intended for anyone who wants a few engaging, simple demonstrations to take into their community for outreach purposes.

Where the activities come from…

The PHOTON (ATE# 0053284) and PHOTON2 (ATE# 0302528) projects of the New England Board of Higher Education were funded by the National Science Foundation's Advanced Technology Education program to develop materials and provide professional development for secondary and post secondary instructors to enable them to teach optical science and photonics technology. The *PHOTON Explorations* were adapted from some of the favorite demonstrations of the projects' participants. We have used them with fifth graders who were part of EASTCONN's Expanding Horizons program, with high school students in Three Rivers Community College's Laser Camp, and as part of distance-learning courses for college students, working technicians and teacher professional development

In many of the following *Explorations*, there is an element of "optical magic" to be investigated. When doing these activities with students, we begin by posing one or more questions while demonstrating the "magic trick." Students are then challenged to explain what they have seen based on their knowledge of light and optics. Finally, we provide practical applications of the principles involved to show that optics is more than magic, it affects students' daily lives. Here, we present one application for each demonstration, you can no doubt think of many more.

Most of these demonstrations and activities use inexpensive and commonly found materials. They have all been student and teacher tested, but it's always a good idea to try them out first. Before doing any optics activities, be sure to find out in advance what the room lighting is like. Usually just turning room lights off is enough, but sometimes you might need to improvise if an activity works best in darkness. We once made a passable reflection hologram on a teacher's desk in a room with broken blinds, proving that excellent conditions are not always necessary.

All of the *Explorations* are available for download as a pdf document at www.photonprojects.org. On the same website you can find links to short video demonstrations of many of the *Explorations*. The PHOTON projects also created a college lab kit and recorded two dozen grainy videos of ourselves doing the experiments. These are also available at www.photonprojects.org. Color versions of many of the photos in these notes are available at www.lasertechonline.org; click on Optics Home Lab photos.

A note on "how it works": The explanations here are aimed at 10-12 year olds, that is, 4th-6th graders in the U.S. Of course you can adjust them to the sophistication of your audience, but if you can explain physics to a ten-year-old you can explain it to anyone.

Tomatoes and Rainbows- What Color Is It?

#1 What color is a tomato?

Can your eyes be fooled by color and lighting? What determines the color you see when you look at an object?

This is an easy demonstration. It's amazing how many kids think that a tomato appears red because it absorbs red light. Perhaps this will convince them otherwise.

Materials:

- A small tomato, plum or tangerine work well. You can also use small colored candies and challenge students to correctly identify the color to win the candy.
- At least two different color LEDs. You could also use a flashlight, covering the end with blue, green or red plastic film.

Procedure:

In a very dark room, hold the tomato in your hand so that only a small portion of the surface is visible. If you are unable to darken the room, place the tomato or a few pieces of colorful candy in a small box so that it is well shaded from ambient light. It helps to paint the inside of the box flat black. Illuminate the tomato or candy with one of the LEDs and observe the color of the illuminated surface. For example, a red tomato illuminated by blue light looks like a purple plum.

What Color is a Tomato?: How it works

The color you see depends on the wavelengths reflected by the object, the wavelengths present in the illumination, and the color sensitivity of your eyes. A red tomato reflects a range of wavelengths, primarily red but also extending into the orange.[1] However, the skin is shiny so that when illuminated by a blue LED much of the blue light is reflected but no red light since the LED does not contain red light. Thus, the tomato looks like a blue or purple plum.

What Color is a Tomato?: Application

Lighting plays an important role in marketing. Figure 1 shows the effect of illumination on a retail store display. Even though the items are identical on both left and right sides of the photo, the difference in lighting creates a large difference in perceived color. Check out the lighting in a local supermarket–are the same lights used for meat and produce? In my hometown, there was a notorious warehouse store where you had to check every item near the windows to see the "real" color. (It's now out of business.) The lighting departments of many hardware stores have displays of different bulbs illuminating the same colors, showing how lighting affects perceived color.

Figure 1. Photo taken at the Southern California Edison Lighting Center, 2004. The displays are the same colors on both sides of the wall, only the lighting is different.

#2 Colors of Light

Is a red light bulb really red? Are some red lights more "red" than others?

OK, so this isn't so much magical (although kids find it really interesting) but it's easy and very inexpensive to do with a big group. Don't forget to mention safety!

Materials:

- Cardboard tube. A paper towel or toilet tissue tube is fine.
- Plastic transmission diffraction grating. If you don't have one handy, you can peel the label from a recordable CD with a piece of tape (scratch the label first then pull off the label with tape). Use sturdy scissors to cut the CD into pieces a bit larger than the tube diameter.
- Aluminum foil or other opaque material for a slit or small hole.
- "CAUTION: DO NOT LOOK AT THE SUN OR INTO A LASER" sticker!

Procedure:

- Cover one end of a cardboard tube with aluminum foil. Hold the foil in place with a rubber band.
- Poke a small hole (about 2-3 mm) in the center of the foil with the point of a pencil or, if you can do it neatly, cut a small slit with a sharp knife.
- Place the diffraction grating or CD piece on the other end of the tube. Usually we don't glue the grating so it can be used without the tube for looking at small sources like a laser spot on a wall.
- Don't forget the safety sticker!
- To use, look through the grating at a light source. For large groups use incandescent and CFL bulbs, ceiling lights, EXIT signs, etc. If the group is small you can use sources they can get close to like an LED, gas tube or laser beam reflected from a piece of paper.

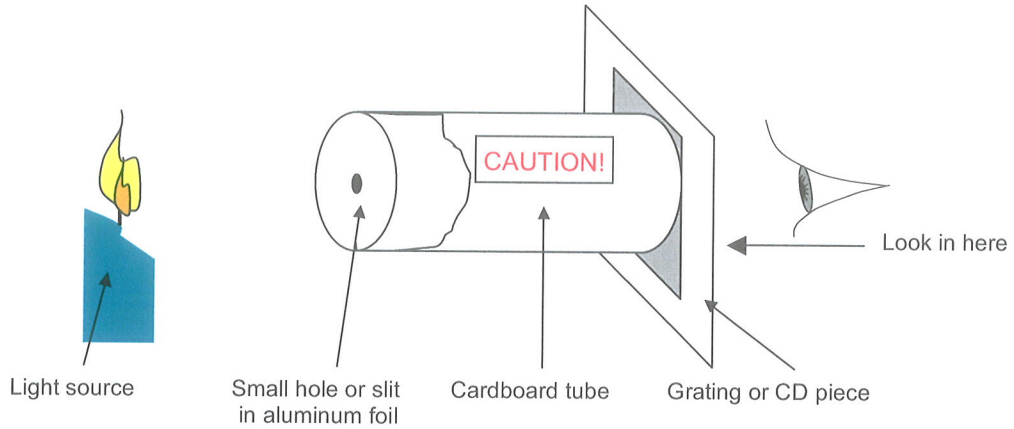


Figure 2. The cardboard tube spectroscope

Colors of Light: How it works

This activity is usually used to the observe spectra and how they are different rather than to explain how a grating works. Whether a continuous spectrum for an incandescent, line spectra for gas tubes or "patches of color" (to quote a fifth grader) for CFL, each source creates light in a different way. Students are encouraged to bring their

"spectroscopes" home and look at light sources around the house- BUT DO NOT LOOK AT THE SUN. (We do explain how to view the solar spectrum by looking at the reflection of sunlight from a piece of white paper.) Neon lights, exit signs and LED indicator lights are also interesting to look at. You can provide crayons or colored pencils so the students can draw what they see, which may be easier than a written description.

Colors of Light: Application

There are lots of spectroscopy applications that appeal to young students. But we like to finish this activity by talking about how you can be fooled by something that seems obvious. We show students a red "party light" bulb and ask them to predict what the spectrum looks like. Nearly every fifth grader will say red, "maybe with a little orange." In fact, with this crude spectroscope, the spectrum is nearly the same as the white frosted incandescent they saw earlier, with plenty of green and some blue. Comparing this spectrum to that of a red LED leads to a discussion of how light is generated by different sources.

Light Rays to Fool Your Eyes

#3 Pinhole Viewer

Can you make an image with just a cardboard box and a pinhole?

We like to do pinhole photography with older kids, making the cameras out of oatmeal boxes. But it's messy and produces potentially hazardous (silver bearing) waste. Here's an easy no-mess version to illustrate the same principle.

Materials

- Large carton or box with the bottom removed
- Aluminum foil
- Needle, tape
- Waxed paper

Procedure:

- Cut a hole 1- 2 cm square in the center of one end of the box. Be sure the edges and corners of the box will not let in any stray light. (You can cover the ends and corners with black electrical tape, if necessary.)
- To make the pinhole, stack 5-6 pieces of aluminum foil cut slightly larger than the hole in the box. Pierce the stack with a needle. The inner foil pieces should have neat pinholes, with clean edges. Tape one of these foil pieces over the hole in the box, centering the pinhole on the larger hole.
- Cut a viewing hole about 10-15 cm square on the back of the carton. Cover the hole with waxed paper and use it as a screen. Aim the pinhole toward an open window (on a bright day) or a lamp (indoors at night). An image will form on the waxed paper at the back of the box. If the box is very large, you may want to make a larger hole/viewing screen to see more of the image.
- What does the image look like? Is it right side up or upside down? What happens if you make the pinhole larger? Is there an optimum size? Why do pinhole photos have such long exposure times?

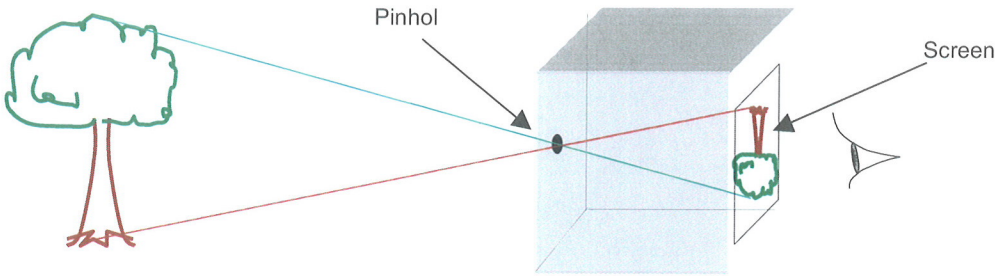


Figure 3. Using the pinhole viewer

Pinhole Viewer: How it works

As you can see in Figure 3, rays of light from the top of the tree pass through the pinhole and strike a small area on the end of the box. The rays from the bottom of the tree do not overlap the rays from the top because of the small size of the pinhole. Thus, an image of the tree is formed on the back of the box. The image is upside down and its size can be found by simple geometry

If the hole is too large, the overlapping rays will form a blurry image, or no image at all. If it's too small, rays passing through will spread by diffraction and also cause the image to blur. To use the box as a camera, film is placed at the image location. Exposure times can be very long (up to several hours).

Note: An excellent tutorial on light and shadows leading to how a pinhole can produce an image is available from the University of Washington Physics Research Group at http://www.phys.washington.edu/groups/peg/pdfs/AJP_1998_Wosilait_etal.pdf.

Pinhole Viewer: Applications

Many photographers enjoy creating pinhole images because of their unusual qualities. A recent (May 2011) issue of *National Geographic Magazine* featured the amazing pinhole photos of Abelardo Morell who turns darkened rooms into giant cameras. On a simpler scale, cardboard cartons and oatmeal containers make simple "recycled junk cameras" that can be used with film paper for quickly developed black and white photos. There are many web references for beginner to accomplished pinhole photographer; a few are listed in the resources at the end of these notes.

A very common (but often unrecognized) pinhole image can be seen under the canopies of leafy trees. The round blotches on the ground are pinhole images of the sun; these round spots turn to crescents during a solar eclipse.

Figure 4. Pinhole photos by Laura (H.H. Ellis Tech HS) takn with a cylindrical box camera. Left: original photo. Middle: scanned and inverted. Right: Actual building. (From Donnelly and Massa, *Light-Introduction to Optics and Photonics*, ©New England Board of Higher Education 2009)

#4 The Amazing Bedazzled Kaleidoscope (hat tip to Barbara Darnell)

How many times can you multiply yourself?

This is a wonderful activity that we quickly adopted upon seeing Barbara's version. Using plastic mirrors makes the giant kaleidoscope more portable but also more expensive.

Materials

- Three large mirrors (we use the kind you mount on the back of a door).
- Duct tape, lots of it
- Optional: Decorations for the backs of the mirrors

Procedure:

- Carefully tape the three mirrors together at their edges. Tape around the two openings as well.
- Optional: Decorate the outside (backs) of the mirrors with jewels, stick-on sparkles, etc. This really grabs attention.
- To use: Have students stand on each end and look into the kaleidoscope opening. Ask: How many faces do you see? Are they complete faces or parts of faces?
- Optional: Try looking at other objects such as a large number "5" (look at the orientation of reflections), or bright colored pictures.

Giant Bedazzled Kaleidoscope: How it works

Kaleidoscopes work by reflection, but the explanation for the formation of multiple images is not a simple exercise, especially for the middle school audience. It helps to have two smaller mirrors to illustrate multiple reflections after students have their curiosity piqued by using the giant kaleidoscope. Place the mirrors so they stand vertically making an angle of around 120°. (It helps to have a "hinge" of tape to hold the mirrors together.) Place a small object such as a cork or rubber stopper between the mirrors. As shown in Figure 5, an image forms in each of the mirrors, as expected. As the angle between the mirrors is made smaller more images appear due to multiple reflections. An interesting exercise is to count the number of images that appear as the angle between the mirrors is made smaller. Using a printed number "5" for the object lets students observe the orientation of the multiple reflections.

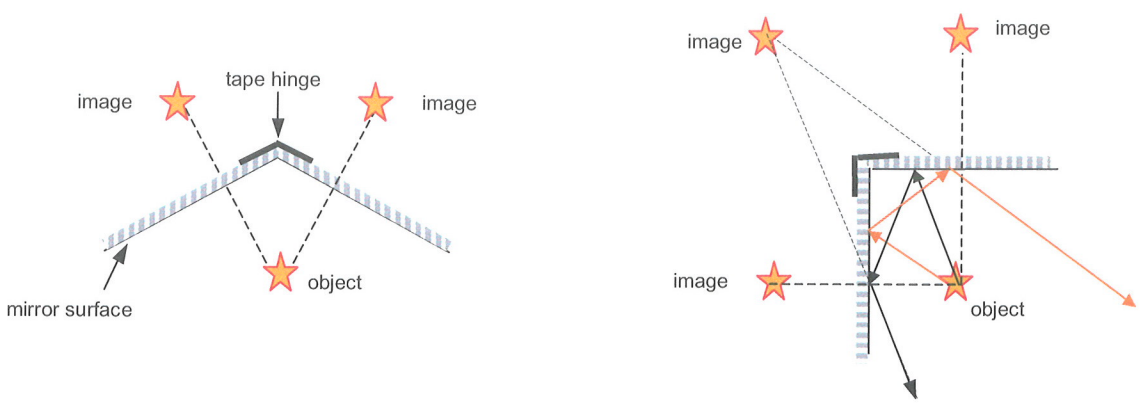


Figure 5. Images formed by two hinged mirrors at 120° (left) and 90° (right).

Giant Bedazzled Kaleidoscope: Application

Since its invention by Sir David Brewster in 1816, the kaleidoscope has been enthusiastically embraced by both curious children and serious artists. The Brewster Kaleidoscope Society (http://www.brewstersociety.com) was founded in 1986 "to share and promote the beauty, creativity, and joy of these mirrored tubes of magic." The society's web site has links to kaleidoscope artists in the U.S., U.K. and Japan as well as diagrams showing how the number and orientation of images change as the angle between the mirrors change.

Figure 6. Using the Giant Bedazzled Kaleidoscope with Jr. Laser Campers (5th grade). Left: looking at faces and right: with colorful stickers on a clear plastic sheet as the object.

#5 The Disappearing Beaker

Can a solid glass beaker disappear before your eyes?

This is a classic demonstration and you can find lots of video presentations on the web. Start by asking what "transparent" means. Students usually reply that it means you can see *through* something. So then how can you see something that's transparent?

Materials:

- Two Pyrex® beakers (preferably without printing), a small one that fits completely inside the larger one. Other types of glass may or may not work – experiment to find out! Also try stirring rods of different types of glass; some will disappear and some will not.
- Inexpensive vegetable oil

Procedure:

- Begin by placing the small beaker inside the larger one, and noting that the inner beaker is plainly visible. (Ask why!)
- Pour some oil into the smaller beaker; is it still visible?
- Continue to pour oil in the smaller beaker until it overflows into the larger beaker. As the space between the two beakers fills with oil, the inside beaker disappears!

There are a lot of variations on this demonstration. You can have the smaller beaker already submerged in the oil, inside the larger beaker. They then break another beaker and place pieces of broken glass into the submerged beaker. After some magic words, they pull out the inner beaker in one piece! The broken pieces can't be seen because they are submerged in the oil inside the smaller beaker.

We should mention that this may also be done with water, which is less messy. Clear water absorbing materials are available in a variety of shapes from science supply houses. When saturated, they are nearly all water so they can't be seen when submerged. It does take a while for this to happen, however.

The Disappearing Beaker: How it works

In order to see an object, some light must leave the object and enter your eye. In the case of a non-luminous object, light must be reflected from the object in order for you to see it. That is, a transparent beaker must reflect at least a small amount of light in order for you to see it. For young students, the explanation is that when light slows down or speeds up, some is always reflected. Light slows down when it goes from air into glass, then speeds up when it leaves. But light travels at about the same speed in glass and in vegetable oil, so there is no reflection.

Older students who know about index of refraction can calculate how much light is reflected. When light strikes glass head-on, the percent of the incident light reflected is given by

$$\%\text{Reflected} = \frac{(n_1 - n_2)^2}{(n_1 + n_2)^2} \times 100$$

For air ($n \approx 1$) and glass ($n \approx 1.5$), about 4% is reflected from each surface. If n_1 is the same as n_2 (glass and oil) then no light is reflected.

The Disappearing Beaker: Application

To minimize the amount of light reflected (and maximize the amount transmitted) the index of refraction (speed of light) in the incident and transmitting media should be as close as possible. Sometimes, "index matching fluids" are used, for example, when two optical fibers are joined in a temporary mechanical splice connection to minimize reflection back into the signal source.

A much more interesting application for many students is the gel applied before an ultrasound examination. Most students (and adults!) think the purpose is to make the transducer slide more easily over the skin. In fact, it is index- matching gel to maximize sound energy transmission from the transducer into the body.

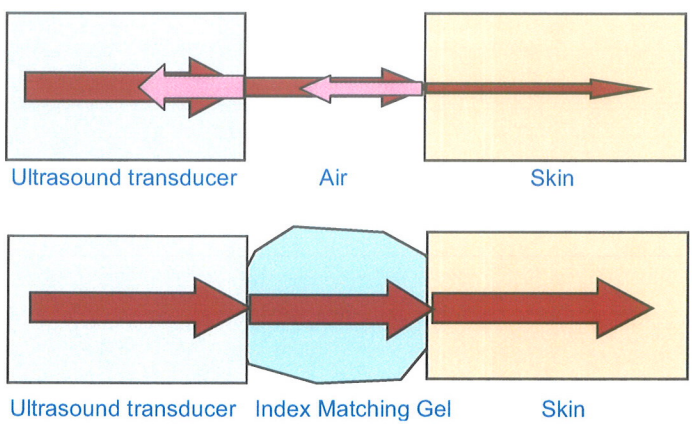


Figure 7. Top: Light traveling from left to right is partially reflected at each surface where the speed of light changes. Bottom: Index (of refraction) matching gel between the ultrasound transducer and skin minimizes back reflection and maximizes the amount of energy entering the body. Why isn't ultrasound used to image lung tissue?

#6 Amazing Jello®

Can you focus light with gelatin? Make a gelatin optical fiber? If you are really clever, can you make a graded index gelatin fiber?

This is another classic activity with a new twist. Younger kids can just observe the bending of light, older students can measure the index of refraction. Don't forget to talk about laser safety! And the rest of us can try to make graded index gelatin.

Materials

- Slabs (around 1.5 cm thick) of very stiff gelatin. You can use plain gelatin or flavored sugar-free. Just don't use the kind with sugar- it makes a sticky mess. *Spray the pan with oil to make it easier to remove the gelatin.*
- Something to cut with–knives work, but 2 cm wide strips cut from a plastic folder can be bent to shape and are less dangerous
- Laser pointer
- Ruler and protractor if you want to take measurements
- Sugar if you want to try GRIN gelatin (see below)

Procedure:

- Make the gelatin in a pan that will allow the gelatin block to be around 1.5 cm thick. If it's too thin it will be hard to handle. Use half the usual amount of water. On flavored gelatin packages, follow the recipe for "blocks" or Jigglers®- (on the Jello® package). You may want to experiment to find the right "mix". Remember to lightly oil the pan to make removal easier.
- To make in quantity, try asking the local butcher for some small plastic meat trays. It's easier to handle in small trays rather than in a large pan. If the gelatin is stiff enough it will not need refrigeration.
- Remove the hardened gelatin carefully and cut into shapes for experimenting- rectangles, think strips or lens shapes as you prefer.
- To measure index of refraction, draw perpendicular lines on a piece of paper. Place the straight side of a gelatin block along one line. The other line is the normal to the surface (See Figure 8). Use a laser pointer to direct a beam into the block. Mark the end of the laser and the spot at the edge of the block where the beam exits. Remove the block to measure the angles of incidence and refraction and use Snell's law to calculate n_2 where $n_1 = 1$ and the angles are measured as shown in Figure 8. High school students should probably be able to handle Snell's law:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

  Point out to younger students which way the beam bends (toward or away from the normal) as it goes from air to gelatin and back into air again.

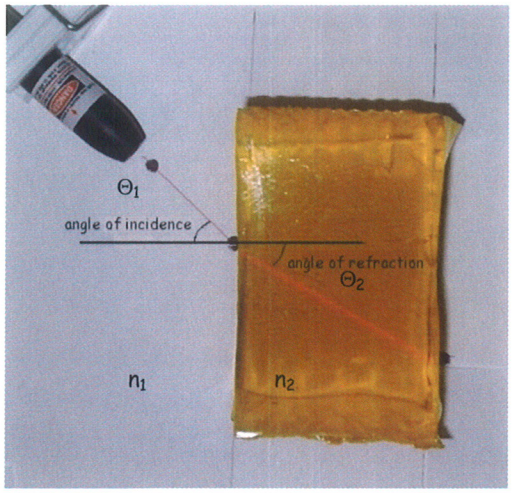


Figure 8. Measuring the index of refraction of gelatin . This photo shows lemon sugar free gelatin. (We think yellow looks cool with a red laser.) Yes, the beam is drawn on the air side.

- Make a gelatin optical fiber! Cut a long thin strip and shine the laser in from one end to illustrate total internal reflection (See Figure 9.) Try slicing the end of the fiber in two pieces along the length. Can you get light to travel down both branches of this "bifurcated fiber"?

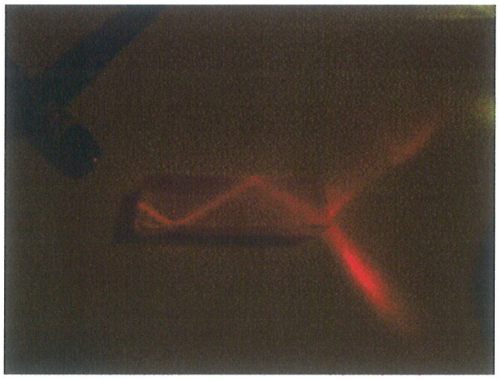


Figure 9. A gelatin "optical fiber" showing total internal reflection

<u>GRaded INdex gelatin</u> (hat tip to Groot Gregory)

- The index of refraction of gelatin can be increased by adding sugar to the mix. To make GRIN gelatin, mix boiling water and gelatin powder as usual for gelatin optics. Then, add as much sugar as you can dissolve. You can make a slab or mold it in a cylinder, like a large plastic medicine container (Figure 8). Remember to coat the inside of the container with oil for easier removal.
- After the sugary gelatin has set, remove it from the container and place it in cold water for a few hours. Sugar will diffuse out from the surface in contact with the water, resulting a gradually changing sugar concentration and thus, a gradually changing index of refraction (See Figure 10).

- It may be possible to make a "step index" fiber by placing a higher gelatin content "core" into a lower gelatin content "cladding." I've had what can at best be called mixed success with this but I haven't given up.

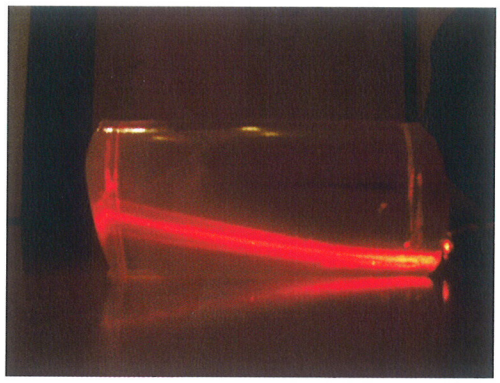


Figure 10. GRIN gelatin. This piece was made in a large (4.5 cm diameter) plastic prescription medicine container. The laser beam enters horizontally from the lower right.

#7 The Misbehaving Lens

Can a double convex lens make light diverge?

Physics books have diagrams like Figure 11, leading students to believe that a lens needs only to be thicker in the middle to bring light to a focus. Is this always true?

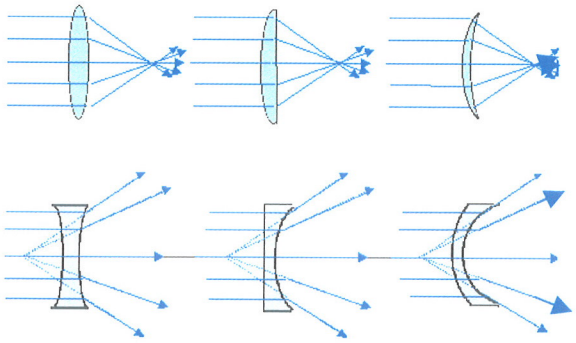


Figure 11. Converging and diverging lenses. . (From Donnelly and Massa, *Light-Introduction to Optics and Photonics*, ©New England Board of Higher Education 2009)

Materials:

- Two watch glasses (from a chemistry lab)
- Silicone adhesive (such as sold for aquarium sealing)
- A transparent water tank large enough to completely submerge the "lens"
- A few drops of milk
- Laser pointer. If you have a laser ray box, it works even better.
- Optional: A glass lens of similar in shape to the "air lens", such as a large magnifying glass.

Procedure:

- Coat the edge of one watch glass with a thick bead of silicone adhesive/sealant. Carefully place the second watch glass on top, creating an air bubble between. Allow to cure thoroughly.
- Fill the tank with water and add a few drops of milk so that the laser beam is visible. Lower the "air lens" into the tank so it is fully submerged. (You will need to hold it in place–an air lens floats!)
- Direct the laser beam through the top, middle and bottom of the lens and notice where the rays travel after being refracted by the lens. Do they converge or diverge?
- If you have a glass converging lens, repeat the demonstration. Explain the difference!

The Misbehaving Lens: How it works

Fifth graders can understand this explanation if they've done the gelatin activity first. We usually refer to the speed of light, not index of refraction, with fifth graders.

When light goes from a medium where it travels faster to where it travels slower, it bends toward the normal (perpendicular) line to the surface. If light goes from a medium where it travels slower to where it travels faster, it bends away from the normal line. Light travels faster through air than it does through water, and faster in water than it does in glass. (See Figure 12.)

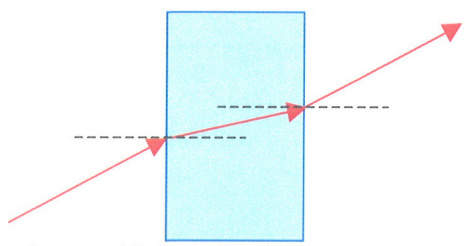


Figure 12. Refraction of a ray of light as it goes from air to glass (blue) and back into air.

So with a glass lens, light moves slower in the lens than in the surrounding air (or water). Light travels *faster* in an air lens than in the surrounding water so light rays behave exactly the opposite from a glass lens.

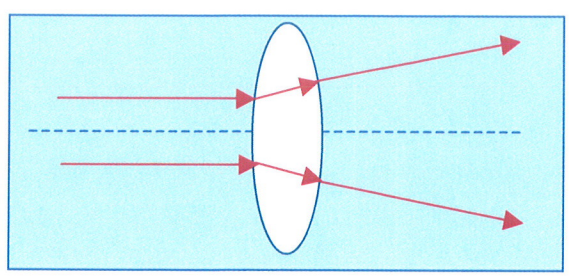


Figure 13. The "air" lens in a tank of water makes light coming from the left bend *away from* the axis.

The Misbehaving Lens: Application

How do swim goggles improve your vision? Your eyes focus light onto your retina, where sensors (rods and cones) detect the image and send the information on to your brain. (Figure 14) But most of the focusing is actually done by the cornea, rather than the lens, because lens power depends in large part on the difference in index of refraction of the lens and surrounding media. Normally, the cornea is surrounded by air. The eye's lens is surrounded by fluids whose index of refraction is not that much different from the lens. However, when you open your eyes underwater, your vision is blurry because the difference in index of refraction between water and your eye is not enough to focus light on the retina- you become severely hyperopic (farsighted). (Figure 15) Swim goggles restore the air film in front of your eye and allow the cornea to do its job (Figure 16).

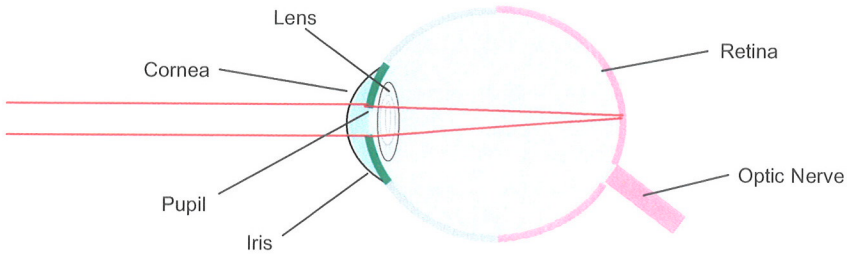


Figure 14. Normal eye in air. Most of the focusing power is due to the cornea.

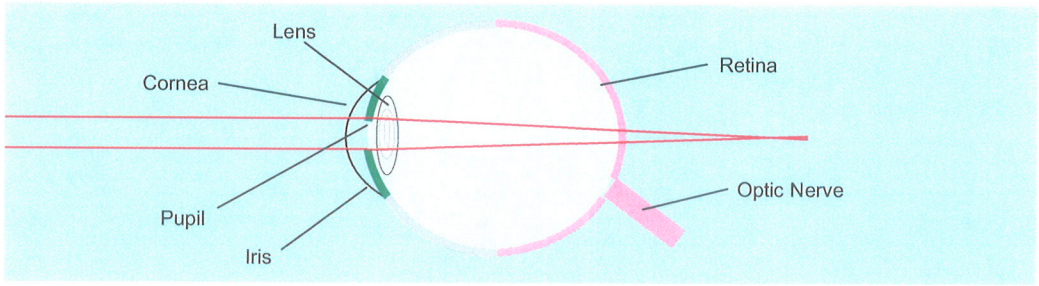


Figure 15. Under water, the index of refraction change between the medium and the cornea is reduced and light from a distant object focuses behind the retina. This is also what happens when a person is hyperopic (farsighted).

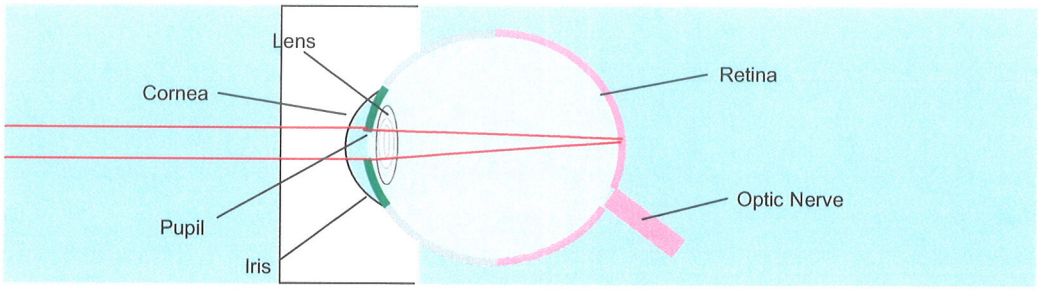


Figure 16. Swim goggles restore the air film at the cornea, allowing the eye to focus.

Polarization Magic

#8 The Magic Box

Can you build a "wall" that solid objects can pass through? Where does the "wall" come from? How do objects pass through it?

This is a very cool illusion. Even people who know how it's done find it fascinating.

Materials:

- A cardboard box about the size of a tissue box. Paint it black for best effect.
- Four 2"-3" squares of polarizing film
- Tape
- For dramatic effect- a knife or chopstick

Procedure: (See Figure 17.)

- Remove rectangles approximately 2" by 4" from both the front and the back of the box. Be sure that each opening can be completely covered by two polarizer squares when they are placed side by side. Carefully align these openings so you can look right through the box.
- Tape two of the polarizing filter squares to the front opening. One filter should have its transmission axis in the vertical direction and the other in the horizontal direction. Tape the other two the polarizing filter squares over the back opening. The orientation of the transmission axes is correct if, when viewed from the front, the vertical polarizers (front and back) are both on the same side. (Figure 16)
- Look through the front of the box. Where did the black wall come from in the center of the box? Optional: carefully stick a knife or choptick into the box from the end- piercing the "wall" with no resistance!

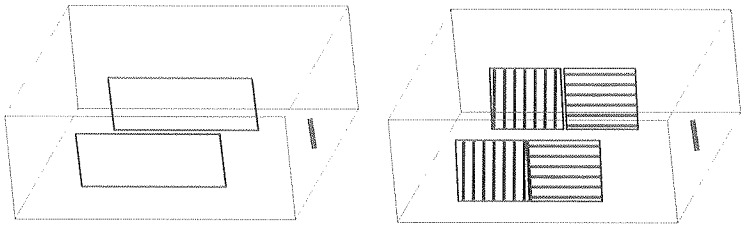


Figure 17. Construction of the Magic Box. Left: Cardboard box with rectangles cut out in the front and, directly opposite, in the back. Right: Polarizers mounted over holes, with transmission axes indicated. The slit on the end is optional, for piercing the "wall"' with a knife or other long thin item.

The Magic Box: How it works

This is easier to explain to fifth graders if they previously worked with some polarization activities. (See the complete list of Explorations in the resources section.) They then should understand that

- Light is a wave that vibrates back and forth at right angles to the direction of motion.
- "Natural" or "randomly polarized" light can vibrate in any direction.
- Polarizing light restricts the vibration direction, for example, a horizontally polarized light wave vibrates only horizontally.

- A polarizing filter acts somewhat like a picket fence, only allowing one direction of wave vibration to pass.

Now suppose that natural light passes through a vertically oriented polarizer. Only vibrations in the vertical direction pass through. What happens if this vertically polarized light strikes a polarizer oriented in the horizontal direction? This second polarizer cannot pass vertical vibration so no light gets through.

Look again at the "wall" in the magic box. Where the horizontal polarizers in the front of the box overlap vertical polarizers in the back of the box no light passes. This is what gives the appearance of a wall in the center of the box.

The Magic Box: Application

Sunlight is randomly polarized; the light waves vibrate in all directions. However, when sunlight is reflected from a surface such as water or snow, it is polarized so that the vibrations are back and forth parallel to the surface. (We prefer to say perpendicular to the plane of incidence but that might be too much for a ten-year-old.) These vibrations can be blocked by a polarizing filter oriented perpendicular to this vibration direction. Polarized sunglasses block glare by preventing the polarized light from passing though.

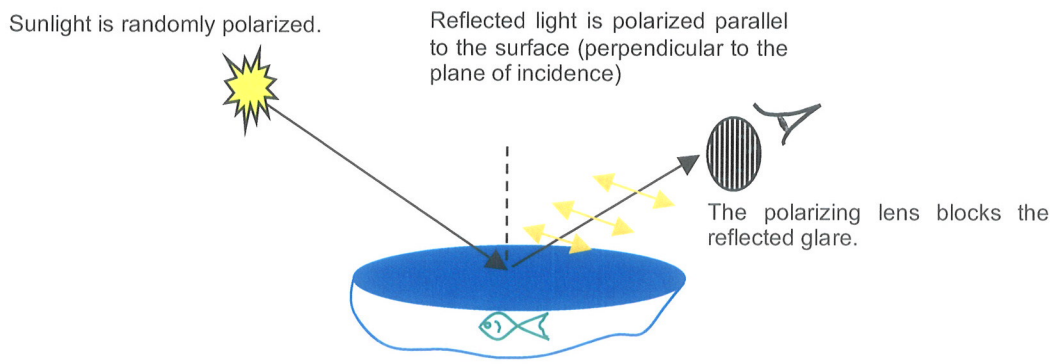


Figure 18. Polarizing sunglasses work because the reflected glare of the sun from water or snow is polarized. The polarizing film mounted in the glasses frame must be in the proper to work.

#9 Polarized Light Art

Can you make colorful art from plain old cellophane tape?

Clear cellophane tape is colorless. However, if it is placed between two polarizing filters, the tape can show brilliant colors. Where do the colors come from? Why do the colors change when the polarizer is rotated?

Materials:

- Two squares of polarizing film
- Cellophane tape or other pieces of cellophane, for example, from vegetable or flower packaging
- A piece of clear plastic, such as transparency film, the same size as the polarizers. This is not necessary, but gluing directly onto the polarizers means they can't be used for other purposes.
- Glue sticks if cellophane is used

Procedure:

- Place small pieces of tape or cellophane on the plastic film. You can attach them directly to the polarizer, but then the polarizer can't really be used for anything else. Attach the tape of cellophane in different directions, and try varying the thickness.
- Make a "sandwich" of the two polarizers with the tape-decorated film in between. Be sure to show students exactly what this looks like; they often put the cellophane pieces on top of the two polarizers by mistake.
- Rotate the top polarizer, while you look through the entire stack. In order to see the colors effectively, the stack should be back lit, for example, hold it up to a window and look through the layers. A photographer's light box works well too.

Polarized Light Art: how it works

Cellophane and other birefringent materials can affect polarized light by changing the direction of vibration of the light wave. For example, if vertically polarized light passes through a piece of cellophane, the direction of polarization will be different on the other side. The exact amount the direction changes depends on the thickness of the cellophane and on the color of the light. The top polarizer passes light of a specific orientation. Since different colors are rotated to different directions, the top polarizer "chooses" which color you see.

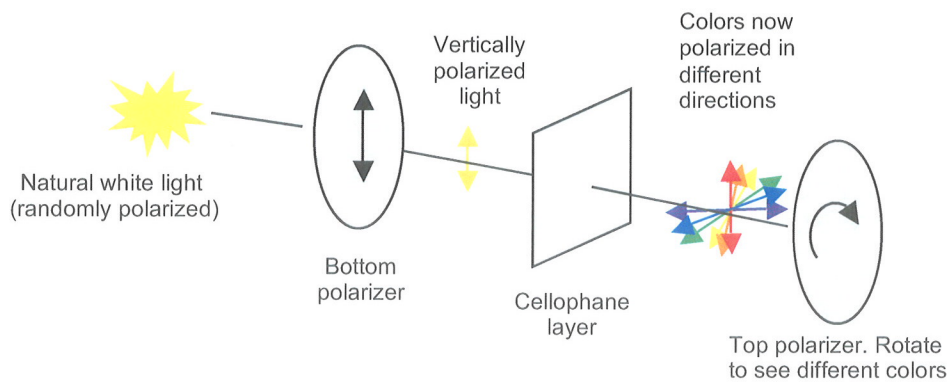


Figure 19. The cellophane rotates the direction of polarization. The amount of rotation depends on the thickness of the cellophane and the wavelength of light.

Polarized Light Art: Application

This technique can be used to create beautiful works of art that change from one image to another as the top polarizer is moved. Austine Wood Comorow, who coined the term Polage®, creates wall-sized art for museums and other public spaces using polarized light. In technology, the effect is used to detect stresses in transparent materials. Plastic and glass behave similarly to the cellophane in this experiment when placed under stress. This principle can be used to detect stress in materials such as glass or plastic. The eyeglass lenses in Figure 20 are subject to stress as can be seen in the right hand part of the photo where the lens is viewed in polarized light

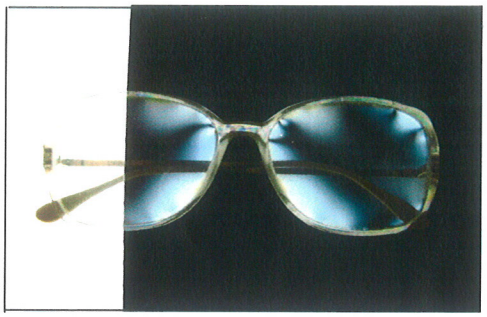


Figure 20. These eyeglasses are resting on a light box covered with a sheet of polarizing film. A second piece of film oriented at right angles to the first is covering the eyeglasses on the right. Stress in the glass lenses is apparent under the top polarizer.

#10 Light You Can't See

How does ultraviolet light work? How do we know it's there if we can't see it?

This is a potpourri of fun activities to do with UV flashlights, glow-in-the-dark materials and UV reactive beads.

Materials:

- UV flashlight (you can use sunlight for some activities as noted below)
- Small flashlight
- Red and blue LEDs
- square of phosphorescent paper or plastic or other "glow in the dark" material
- whitening detergent
- cotton swabs
- UV beads

Procedure:

- *Phosphorescence*: This works best with the room lights off, but it does not need to be really dark. Shine the flashlight onto the square of phosphorescent material and observe the glow after the light is removed. Predict what will happen if you shine the red and blue LEDs on the material, then test your predictions. Why doesn't the red light have any effect? Do you think a flashlight will work? Why?
- *Fluorescence:* This works best in a dark room. Use a cotton swab to write a "secret message" with the detergent on a piece of paper. Illuminate with the UV light. Does it continue to glow when the UV light is removed? Why not? How is this different from the glow-in-the dark material, which continues to glow when the light is turned off?
- *UV beads*: These can be illuminated with the UV light or just expose them to sunlight. Use the beads to test sunscreens! Choose a single color bead and dip some in sunscreen. Use different SPF factors if you can. You might also just cover some of the beads with different types of fabric to see which ones are better at blocking ultraviolet light. Put the beads on a plate and leave some uncovered and some completely covered. Take all the beads out in the sunlight (or use a UV flashlight) and after a few minutes compare the color of the covered, uncovered and sunscreen or fabric protected beads.

Note: If the beads are hard to handle, they can be glued to popsicle sticks for ease of handling. Cover a pan with aluminum foil and place the beads flat on the foil. Put in a 300°F oven for about 15 minutes until the beads are flattened. (They will look clear at this stage.) After the flattened beads are cooled they turn white again. At this point, glue them onto the sticks and proceed as above. The *Nanosense* web site in the Resources section has complete instructions.

Things that Glow in the Dark: How it Works

Visible light is produced when atoms in a high-energy ("excited") level return to a lower energy level. Atoms and molecules can be excited in a number of ways, for example, when an atom absorbs light or is subjected to a high voltage. The excited atoms in a material may all give off light energy quickly in which case it is called fluorescence. Or, the atoms may release light energy over a longer period of time, which is called phosphorescence.

The ultraviolet light waves used in this exploration have high energy. By comparison, blue light has lower energy and red light has lower energy still. Red light does not have enough energy to energize the phosphorescent material. The more energetic blue light can provide enough energy to excite the material, and then it continues to glow for a while. Why does the white light of the flashlight work?

UV beads don't really fit in the "glow in the dark" category because they are neither fluorescent nor phosphorescent. Instead, they contain a polychromic dye molecule that changes shape when illuminated by UV light. The new shape absorbs visible light and so appears colored.

A note on the sunscreen experiment: The SPF factor on sunscreen bottles is a measure of UVB protection, but the UV flashlights are usually around 395 nm (UVA). UV beads respond to the relatively narrow range 300 nm-360 nm, which includes the high energy part of UVA (320-400 nm) and low energy part of UVB (280-320 nm). With older students this might lead to a discussion of the validity of using the beads and/or flashlights to test SPF of sunscreens.

Things that Glow in the Dark: Application

The detergent contains "whitener" that fluoresces when activated by UV light. This makes your white clothes look clean and bright in the sun. Certain toothpastes and eye drops are also fluorescent. Among other common fluorescent items are petroleum jelly and urine; in fact, some UV flashlights are advertised as "urine detectors." Spelunkers carry UV flashlights to seek out scorpions, which glow under UV light (except when molting; only the hardened exoskeleton glows). Finally, Avon® sells a "skin analysis" UV lamp that reveals certain skin conditions (sun damage, dry or oily skin, etc) – all treatable with Avon® products, of course.

Sources for Materials

The supplies for these experiments can be purchased from many sources; we list only one or two that we have purchased from recently.

- *What color is a Tomato?* Very bright (and expensive) PHOTON® LEDs are available from a number of sources, such as www.photonlight.com. They can sometimes be found at lower prices at sports and novelty shops
- *Colors of Light.* Diffraction gratings of all kinds are inexpensive in large quantities from Rainbow Symphony Store (www.rainbowsymphonystore.com.) If you'd prefer to buy cardboard tubes (rather than have your friends and family collect them) 1.5" x 9" mailing tubes are sold in boxes of 50 by a number of vendors. Check around for best price.
- *Pinhole Viewer.* The best part of this activity is that there's nothing to purchase! A more durable pinhole can be made of a piece cut from a soda can. Creating actual pinhole photos is fun, but be sure to check on local regulations for silver-bearing waste disposal. We like Ilford brand black and white film paper and liquid developer and fixer, which are easier to mix than powders. We purchase from a local photography shop when we can but if none is available. B & H Photo in New York city is a good supplier (www.bhphotovideo.com}.
- *Amazing Bedazzled Kaleidoscope* Oriental Trading Company has inexpensive kaleidoscope kits (www.orientaltrading.com). We've found plastic mirrors to be expensive, which is why we make our giant version with door mirrors from a "big box" store.
- *The Disappearing Beaker.* A pair of standard laboratory beakers works well but they usually have markings. If this is a problem, beakers with no markings can be purchased from Educational Innovations (www.teachersource.com).
- *The Misbehaving Lens.* Watch glasses are available from standard physical science suppliers. Most chemistry departments have plenty to share. Silicone adhesive can be found locally at stores that sell aquarium supplies or in home/hardware stores. For a water tank, we use a small pet carrier tank from a pet shop when a large aquarium is too large to work with. Large lenses can often be found at American Science and Surplus American Science and Surplus (www.sciplus.com). Another source of cheap lenses (and other optics) is Surplus shed (www.surplusshed.com)
- *The Magic Box* and *Polarized Light Art.* For inexpensive polarizing film (especially in quantity) try www.polarization.com. Polarization.com is also a great source of information on polarized light applications.
- *Light you Can't See.* Phosphorescent vinyl is available in small pieces from a number of suppliers such as Educational Innovations (www.teachersource.com) or Anchor Optics (www.anchoroptics.com). Glow in the dark paper is less expensive and available from some craft shops. UV beads are pretty easy to find, but our usual source is Educational Innovations, which sells bags of 3000 beads (and includes information on how they work). They also carry UV flashlights. There are less expensive UV flashlights around, but some seem to be poor quality. One source of cheap UV flashlights (as well as LEDs, laser pointers and cheap batteries) is Jack's Tool Shed (http://jackstoolshed.net/).

Other Resources (Free Stuff)

- These are all available at http://www.photonprojects.org
  - The PHOTON Explorations (pdf file)
  - Links to videos of students performing the PHOTON Explorations
  - Links to PHOTON Lab Kit experiment videos ("Laser Geeks Present")
  - Papers and publications by teachers on their classroom and outreach projects
  - Link to the PHOTON PBL problem based learning Challenges
- References for pinhole photography
  - National Geographic issue May 2011 http://ngm.nationalgeographic.com/2011/05/camera-obscura/oneill-text
  - Worldwide Pinhole Photography Day http://www.pinholeday.org/
  - Oatmeal box pinhole camera – complete how-to with photos http://users.rcn.com/stewoody/
- Photos and videos of polarized light art and information on how it is created. Watch Austine at work! http://www.austine.com
- Experiments in Nanotechnology, including more on sunscreen testing at www.nanosense.org
- Links to optics applets and tutorials, assorted photos of "home lab" experiments and other neat optical effects http://www.lasertechonline.org.
- Great solar-related activities and links http://solar-center.stanford.edu/
- Arbor Scientific's *CoolStuff Newsletter* has great ideas for demonstrations and activities. The archives are at www.arborsci.com/CoolStuff/Archives3.aspx. Many of the activities here are also in the *CoolStuff* archives.
- SPIE has free posters and videos at http://spie.org/x30114.xml
- OSA's free posters at http://www.osa.org/educationresources/youtheducation/
- The *CRISP Website for Educators* has great ideas for demonstrations and activities. Access materials at https://www.southernct.edu/crisp/index.php. CRISP is a National Science Foundation Materials Research Science and Engineering Center (MRSEC) at Yale with components at Southern Connecticut State University (SCSU).
- University of Washington Physics Education Group http://www.phys.washington.edu/groups/peg/

References

[1] Georgia State University Hyperphysics project, "Spectral Reflectance of a tomato", http://hyperphysics.phy-astr.gsu.edu/hbase/vision/spd.html

[2] Donnelly, J. and Massa, N. LIGHT-Introduction to Optics and Photonics, a general textbook on light and optics, available from http://stores.lulu.com/photon2

[3] Clear Sunscreen: How Light Interacts with Matter, The NanoSense Project, Center for Technology in Learning. SRI International, http://nanosense.org

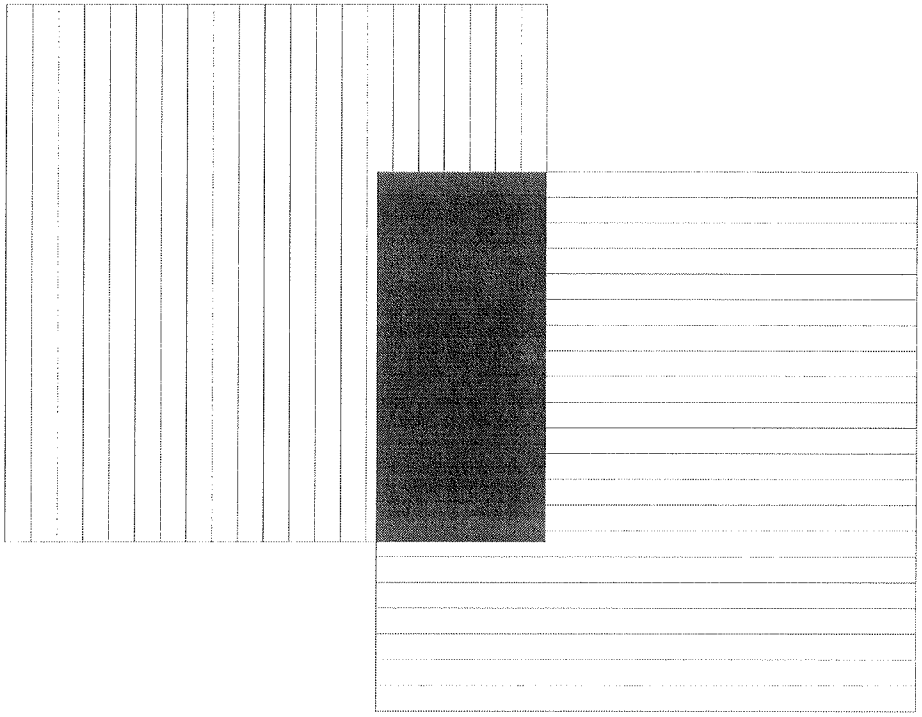
POLARIZING FILTER DEMO KIT

Educational Innovations Inc.

Educational Innovations INC®

PF-1

Polarizing Filter Demo Kit



Materials:	2	polarizing filters, 3" x 3"
	10	sheets of acetate
	1	roll of optically active cellophane tape
	1	calcite crystal (Iceland spar)
	1	Plexiglas stress tester
	1	piece of polyethylene
	1	piece of mica

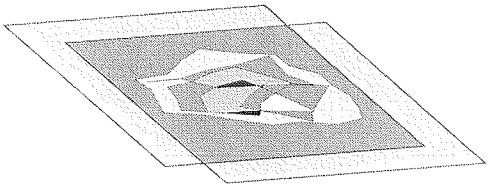
5 Francis J. Clarke Circle
Bethel, CT 06801
www.teachersource.com

Phone (888) 912-7474
Fax (203) 229-0740
info@teachersource.com

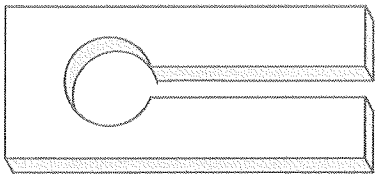
When two polarizing filters are placed atop one another, they can be transparent or opaque to light. By rotating one of the filters, the transmitted light passing through the filters may be turned "on" or "off". When the filters do not transmit light, the polarizing filters are said to be "crossed polarizers". Certain materials such as cellophane tape, Plexiglas, corn syrup, and stretched polyethylene exhibit beautiful colors when placed between two crossed polarizing filters.

Experiments:

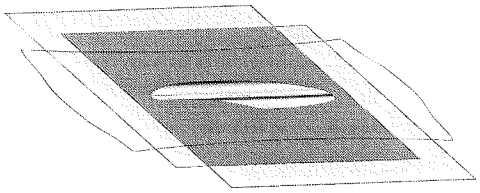
1. Place a piece of mica between two crossed polarizing filters. Each color represents a different thickness of the mica. Try rotating one polarizing filter. Try rotating the mica.



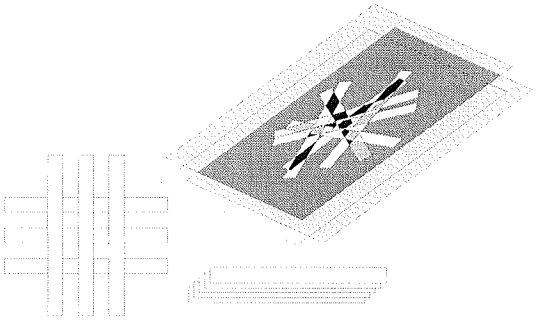
2. When a piece of Plexiglas is placed between two crossed polarizing filters and squeezed, stress lines appear. Engineers use this method to discover the stress areas in new structural designs.



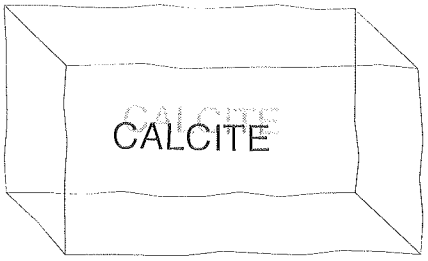
3. Place a piece of polyethylene between two crossed polarizing filters. Then stretch the polyethylene by pulling it. Examine the stretched polyethylene sheet between the crossed filters.



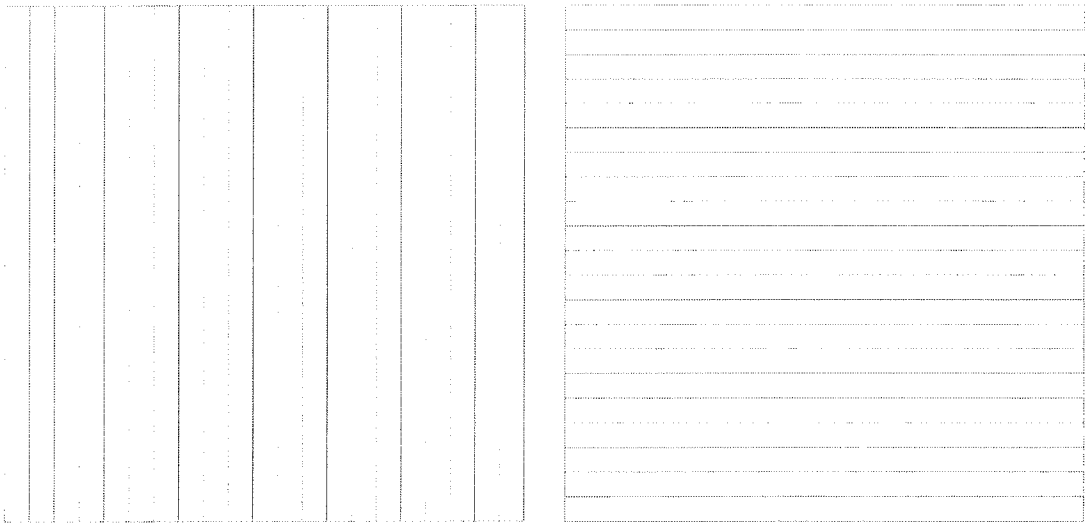
4. Use the special cellophane tape to create designs on a sheet of acetate. Then examine the results by placing it between two crossed polarizing filters. Rotate one of the filters.



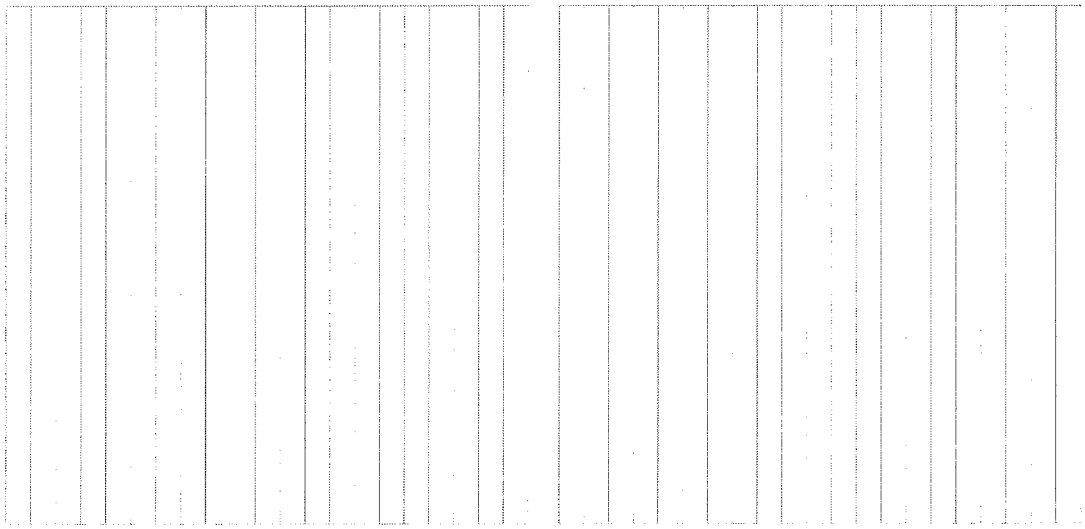
5. If you look at the words on a printed page through a crystal of calcite, you will see double. These natural, nearly transparent crystals exhibit the property of "birefringence", i.e. they break light into two distinct polarized beams. By rotating a polarizing filter over the crystal, it is possible to view one image at a time. This phenomenon can be displayed using an overhead projector.



POLARIZERS



Only vertically oriented light waves may pass through the polarizing filter on the left. Only horizontally oriented light waves may pass through the filter on the right. If the filter on the left is placed on top of the filter on the right, no light will be able to pass through at all.



If the polarizing filters are aligned parallel to each other, light may pass freely through both filters. By placing transparent objects between two polarizing filters, it is possible to identify those materials which rotate polarized light!

Try sandwiching a plastic baggie between two filters and stretching it. When certain plastics are put under stress, they rotate polarized light. Try placing transparent tape between two polarizing filters. Some brands of tape work better than others. The more layers of tape, the more light is rotated.

Educational Innovations, Inc.
5 Francis J. Clarke Circle
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Hermograph's Spectrum Viewer for Elements, Mixtures and Molecules

Hermograph Press

Notes for Hermograph's *Classroom Astronomer*
Spectrum Viewer for Elements, Mixtures and Molecules

This text can be freely duplicated for classroom use.

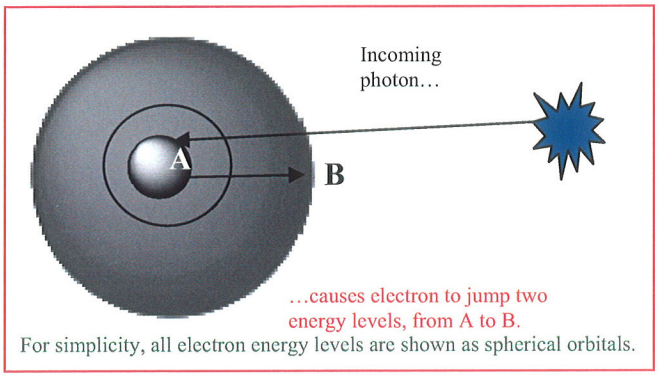
How are spectra made?

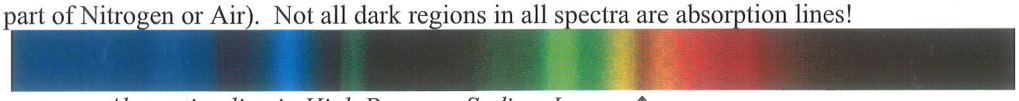
There are three kinds of spectra, though sometimes they can be viewed together.

All spectra require a source of energy (heat). Hot objects produce a **continuous background spectrum,** such as seen in the background of "impure" hydrogen spectra and most of the others here, such as Iodine (I) or Oxygen (O). This is a macroscopic spectrum that has more to do with the atom reacting to heat rather than something atomic, as in the case of the next two types of spectra.

Continuous Spectrum

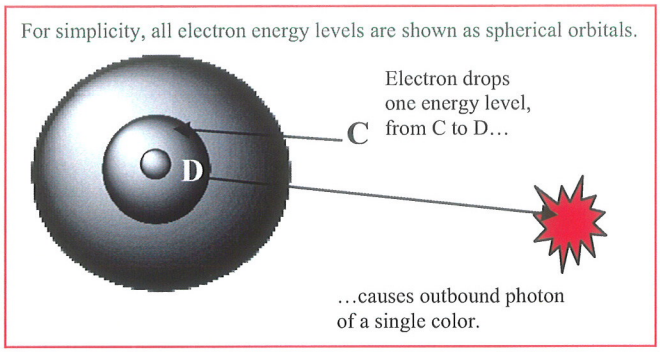
Dark lines or absorption lines: An element (a single atom of a specific substance, like Helium) has a nucleus of protons and neutrons (not involved with spectra), surrounded by "clouds" where electrons will be found. These "clouds" are centered at different distances from the nucleus and correspond to higher levels of electron energy. If an electron in a lower energy-level "cloud" receives the precise amount of energy it needs to jump to a higher level, it will absorb that photon of energy/light and rise to that specific energy-level. It cannot jump just part-way; it is all the way or no jump at all. If that electron is in material, such as a gas, in front of the heat source that produces a continuous spectrum, you will see a dark gap in front of the background spectrum (see the thin absorption line in the red in the Oxygen spectrum, or the large dark bands in the green part of Nitrogen or Air). Not all dark regions in all spectra are absorption lines!





Absorption line in High Pressure Sodium Lamp ↥

Bright lines (emission spectra or emission lines) seen in most of the spectra on the Viewer are also caused by specific photons of energy that match the gaps between different energy-levels in the element's (or elements' or molecules') atomic structure. In this case, though, it is from an electron already in a higher energy-level. Electrons, however, prefer to be as close to the nucleus as possible. As soon as it can, a higher-level electron will release the precise amount of energy (also known as a quantum of energy) to slip down to a lower energy-level in the atomic cloud around the atom's nucleus, not necessarily the energy-level it came from. In doing so it releases the energy as light, a single ray of a particular wavelength of light, which we see as color.



Emission ↥ Absorption ↥

Low Pressure Sodium Lamp with emission and absorption lines

Notes for Hermograph's *Classroom Astronomer*
Spectrum Viewer for Elements, Mixtures and Molecules

Usage tips

1) Sometimes, especially for distant or tiny sources of light, a slight vertical shaking of the Viewer will extend the visible features into lines instead of dots, providing a better match up to the comparison spectra.

2) The measuring scales are only approximations. Do not rely on them for precision measures of visible lines.

3) The best way to identify a spectrum source is to a) identify the brightest/strongest line that is visible, by color; b) use that to find those comparison spectra with the same strongest line, marked with a white dot below it, to eliminate the other spectra; c) count how many bright lines are visible (OR key dark absorption features) in total and in the red, green, and blue-violet regions; and (d) check those counts against the spectra you've selected in (b).

4) You can also adjust the distance of the Viewer card so that the spectra in the window is to the same scale of the comparison spectra and match up the lines and patterns directly.

WARNINGS!

1) **Under no circumstances should you use the Spectrum Viewer to see the spectrum of the Sun!** The Viewer does nothing to stop the Sun's harmful rays or reduce intensities, and damage to the eye can be immediate. Hermograph Press, *The Classroom Astronomer*, and its personnel and related companies cannot and will not be held responsible for injuries or damages by the use of this product, accidentally or deliberately, for attempting to view the solar spectrum.

2) The film in the Viewer window is sensitive to the oils in human fingernails. Do NOT touch the film! It can eat away the film and its diffraction grating rulings. Fingerprints can be removed with isopropyl alcohol--dabbed on with an eye-glass cleaning cloth, some film cleaners, or anti-static cleaners but these, too, can ultimately degrade the film. You can add a piece of transparent film, such as for use with overhead transparencies, on each side to protect the film if you wish. Degraded-by-usage/fingerprints Viewers can not be returned.

3) The colors you see with your eye may not completely match up the hues in the comparison spectra for a variety of reasons. Not all eyes see all colors exactly the same, and some can see a bit into the ultraviolet (UV) or infrared (IR). Both film and digital cameras have different responses to each color/wavelength of light than human eyes do. Even the printing process itself, exposure to light (or age of the unit, over time) can cause the colors to differ and to change.

Notes about the spectra of various gas tubes

Not all gas tubes are created equal. Some may have trace elements, and most react badly to being turned on for long periods. In such cases, element lines may flare from invisible to dramatic, such as the yellow line in Chlorine and Air. In other cases, trace impurities or heat or molecules made of the otherwise-single element may cause a continuous background spectrum, as frequently observed in Hydrogen gas tubes.

Note that the spectrum of Hydrogen and Deuterium (Hydrogen with an extra neutron) are indistinguishable at this scale of observation. It requires an industrial or graphical spectrophotometer to see the slight changes in the main lines of Hydrogen-alpha (red), -beta (blue), etc.

School Contacts by University

Cornell

Elementary Schools:

Northeast Elementary School	425 Winthrop Dr. Ithaca, NY 14850	(607) 257-2121
Belle Sherman Elementary School	501 Mitchell St, Ithaca, NY 14850	(607) 274-2206
Cayuga Heights Elementary School	110 E Upland Rd, Ithaca, NY 14850	(607) 257-8557
Fall Creek Elementary School	202 King St, Ithaca, NY 14850	(607) 274-2214
South Hill Elementary School	520 Hudson St. Ithaca, NY 14850	(607) 274-2129
Beverly J Martin School	302 W Buffalo St, Ithaca, NY 14850	(607) 274-2209
Ithaca Waldorf School	20 Nelson Rd, Ithaca, NY 14850	(607) 256-2020

Middle Schools:

Boynton Middle School	1601 N Cayuga St, Ithaca, NY 14850	(607) 274-2241
De Witt Middle School	560 Warren Rd, Ithaca, NY 14850	(607) 257-3222
Immaculate Conception School	320 West Buffalo Street, Ithaca, NY 14850	(607) 273-2707
Newfield Central School	247 Main St, Newfield Hamlet, NY 14867	(607) 564-9955
Lansing Middle School	6 Ludlowville Rd, Lansing, NY 14882	(607) 533-4271
Groton Middle School	400 Peru Rd, Groton, NY 13073	(607) 898-5803
Spencer Van Etten Central School	16 Dartts Cross Rd, Spencer, NY 14883	(607) 589-7140

High Schools:

Ithaca High School	1401 N Cayuga St, Ithaca, NY 14850	(607) 274-2143
Cascadilla School	116 Summit Ave, Ithaca, NY 14850	(607) 272-3110
Lansing High School	300 Ridge Rd, Lansing, NY 14882	(607) 533-3020
Charles O Dickerson High School	100 Whig St, Trumansburg, NY 14886	(607) 387-7551

UNIVERSITY OF CALIFORNIA, LOS ANGELES

Contact: Enrique Ainsworth (310) 206-6493

The following schools were identified by MESA.

Middle Schools:

Daniel Webster	11330 Graham Pl. Los Angeles, CA. 90064-3725	(310) 235-4600
John Burroughs	600 S. McCadden Pl. Los Angeles, CA. 90005	(323) 549-5000
LACES	5931 W. 18th St. Los Angeles, CA. 90035	(323) 549-5900
Monroe	10711 S. 10th Ave. Inglewood, CA. 90303-2015	(310) 680-5310
Ralph Waldo Emerson	1650 Selby Ave. Los Angeles, CA. 90024	(310) 234-3100

High Schools:

City Honors	155 W. Kelso St. Inglewood, CA. 90301-2237	(310) 680-4880
Dorsey	3537 Farmdale Ave. Los Angeles, CA. 90016	(323) 298-8400
Fairfax	7850 Melrose Ave. Los Angeles, CA. 90046	(323) 370-1200
Hamilton	2955 S. Robertson Blvd. Los Angeles, CA. 90034	(310) 280-1400
Los Angeles	4650 W. Olympic Blvd. Los Angeles, CA. 90019	(323) 900-2700
LACES	5931 W. 18th St. Los Angeles, CA. 90035	(323) 549-5900
Morningside	10500 S. Yukon Ave. Inglewood, CA. 90303	(310) 680-5230
University	11800 Texas Ave. Los Angeles, CA. 90025	(310) 914-3500
Westchester	7400 W. Manchester Ave. Los Angeles, CA. 90045-2399	(310) 338-2400

California Institute of Technology

The following schools were identified by Harrison Orr (UA).

Middle Schools:

Charles W. Eliot	2184 Lake Ave. Altadena, CA. 91001	(626) 794-7121	51.1% Hispanic, 34.3% Black
Washington	1505 N. Marengo Ave. Pasadena, CA. 91103	(626) 798-6708	77.5% Hispanic, 19.6% Black
Woodrow Wilson	300 Madre St. Pasadena, CA. 91107	(626) 449-7390	63.3% Hispanic, 22.6% Black

High Schools:

Blair	1201 S. Marengo Ave. Pasadena, CA. 91106	(626) 396-5820	56.4% Hispanic, 29.7% Black
John Muir	1905 Lincoln Ave. Pasadena, CA. 91103	(626) 798-7881	45.9% Hispanic, 47.8% Black
Pasadena High School	2925 E Sierra Madre, Blvd. Pasadena, CA. 91107	(626) 798-8901	47.2% Hispanic, 25.2% Black
Rose City	351 S. Hudson Ave. Pasadena, CA. 91109	(626) 795-9541	62.4% Hispanic, 30.7% Black

UNIVERSITY OF SOUTHERN CALIFORNIA

Contact: Larry Lim (213) 740-1999

The following schools were identified by MESA.

Middle Schools:

32nd St. Performing Arts Magnet	822 W. 32nd St. Los Angeles, CA. 90007-3699	(213) 748-0126
Barack Obama Global Prep	1700 W. 46th St. Los Angeles, CA. 90062	(323) 421-1700
Bret Harte	9301 S. Hoover St. Los Angeles, CA. 90044	(323) 242-5400
Bud Carson	13838 Yukon Ave. Hawthorne, CA. 90250-7716	(310) 676-1908
Foshay	3751 S. Harvard Blvd. Los Angeles, CA. 90018	(323) 373-2700
Edison	6500 Hooper Ave. Los Angeles, CA. 90001	(323) 826-2500
Hawthorne	4366 W 129th St. Hawthorne, CA. 90250-5211	(310) 676-0167
Prairie Vista	13600 Prairie Ave. Hawthorne, CA. 90250-7306	(310) 679-1003
South Gate	4100 Firestone Blvd. South Gate, CA. 90280	(323) 568-4000
Synergy Kinetic	1420 E. Adams Blvd. Los Angeles, CA. 90011	(323) 846-2225

High Schools

Alhambra	150 E. St. Martinez, CA. 94553	(925) 313-0440
Belmont	1575 W. 2nd St. Los Angeles, CA. 90026	(213) 241-4300
Bravo Medical	1200 Cornwell St. Los Angeles, CA. 90033-1417	(323) 227-4400
Culver City	4401 Elenda St. Culver City, CA. 90230	(310) 842-4200
Foshay	3751 S. Harvard Blvd. Los Angeles, CA. 90018	(323) 373-2700
Fremont	7676 S. San Pedro St. Los Angeles, CA. 90003-2399	(323) 565-1200
Hawthorne	4859 W. El Segundo Blvd. Hawthorne, CA. 90250	(310) 263-4400
Manual Arts	4131 S. Vermont Ave. Los Angeles, CA. 90037	(323) 846-7300
Palisades Charter	15777 Bowdoin St. Pacific Palisades, CA. 90272	(310) 454-0611
South East	2720 Tweedy Blvd. South Gate, CA. 90280-5539	(323) 568-3400
South Gate	3351 Firestone Blvd. South Gate, CA. 90280-2985	(323) 568-5600
Venice	13000 Venice Blvd. Los Angeles, CA. 90066-3589	(310) 577-4200
Washington Prep	10860 S. Denker Ave. Los Angeles, CA. 90047	(323) 418-4000

UNIVERSITY OF CALIFORNIA, SAN DIEGO

The following schools were identified by Harrison Orr (UA).

Middle Schools:

Pacific Beach	4676 Ingraham St. San Diego, CA. 92109	(858) 273-9070	67.4% Hispanic, 7% Black

High Schools:

Mission Bay	2475 Grand Ave. San Diego, CA. 92109	(858) 273-1313	52.3% Hispanic, 14.5% Black

The following schools were identified by MESA.

Middle Schools:

Borrego Springs	2281 Diegueno Rd. Borrego Springs, CA. 92004	(760) 767-5335
Challenger	10810 Parkdale Ave. San Diego, CA. 92126	(858) 586- 7001
Del Dios	1400 W. 9th Ave. Escondido, CA. 92029	(760) 432-2400
Keiller	7270 Lisbon St. San Diego, CA. 92114	(619) 263-9266
Mann	4345 54th St. San Diego, CA. 92115	(619) 582-8900
Millennial	1110 Carolina Lane, San Diego, CA. 92102-3713	(619) 527-6933
Mission	2310 Aldergrove Ave. Escondido, CA. 92029	(760) 432-2400
Montgomery	2470 Ulric St. San Diego, CA. 92111-6036	(858) 496-8330
Roosevelt	3366 Park Blvd. San Diego, CA. 92103-5207	(619) 293-4450
Vista La Mesa	8025 Lincoln St. Lemon Grove, CA. 91945	(619) 825-5600

High Schools:

Borrego Springs	2281 Diegueno Rd. Borrego Springs, CA. 92004	(760) 767-5335
Hoover	4474 El Cajon Blvd. San Diego, CA. 92115-4397	(619) 283-6281
Kearny SCT	7651 Wellington Way, San Diego, CA. 92111	(858) 496-8370
King	Chavez: 500 30th St. San Diego, CA	(619) 744-3828
Lincoln	4777 Imperial Ave. San Diego, CA. 92113	(619) 266-6500
Morse	6905 Skyline Dr. San Diego, CA. 92114	(619) 262-0763
Orange Glen	307 Orange Ave. Chula Vista, CA. 91911-4158	(619) 691-5974
San Diego Educational Complex	1405 Park Blvd. San Diego, CA. 92101	(619) 525-7455
San Pasqual	3300 Bear Valley Parkway South, Escondido CA. 92025-7699	(760) 291-6000
Twain	6402 Linda Vista Rd. San Diego, CA. 92111	(858) 496-8260

UNIVERSITY OF CALIFORNIA, BERKELEY

The following schools were identified by Harrison Orr (UA).

Middle Schools:

Longfellow	1500 Derby St. Berkeley, CA. 94703	(510)644-6360	44.7% Black, 30% Hispanic
Martin Luther King	1781 Rose St. Berkeley, CA. 94703	(510) 644-6280	29.3% Black, 22% Hispanic
Willard	2425 Stuart St. Berkeley, CA. 94705	(510) 644-6330	48.7% Black, 15.2% Hispanic

High Schools:

Berkeley Alternative	2701 Martin Luther King Jr. Way, Berkeley, CA. 94704	(510) 644-6159	78.1% Black, 18.8% Hispanic
Berkeley	1980 Allston Way, Berkeley, CA. 94704	(510) 644-6120	36% Black, 14.4% Hispanic

NORFOLK STATE UNIVERSITY

The following schools were identified by Harrison Orr (UA).

Middle Schools:

Blair	730 Spotswood Ave. Norfolk, VA. 23517	(757) 628-2400	69.4% Black
Lafayette-Winona	1701 Alsace Ave. Norfolk, VA. 23509	(757) 628-2477	86.7% Black
Lake Taylor	1380 Kempsville Rd. Norfolk, VA. (757) 892-3230	85.6% Black	
Norview	6325 Sewells Point Rd. Norfolk, VA. (757) 852-4600	81.6% Black	
Rosemont	1330 Branch Rd. Norfolk, VA. (757) 852-4610	72.2% Black	
Ruffner	610 May Ave. Norfolk, VA. (757) 628-2466	94.9% Black	

High Schools:

B. T. Washington	1111 Park Ave. Norfolk, VA. 23504	(757) 628-3575	86.2% Black
Granby	7101 Granby St. Norfolk, VA. 23505	(757) 451-4110	52.9% Black
Lake Taylor	1384 Kemsville Rd. Norfolk, VA. 23502	(757) 892-2300	72.7% Black
Maury	322 Shirley Ave. Norfolk, VA. 23517	(757) 628-3344	59.6% Black
Norview	6501 Chesapeake Blvd. Norfolk, VA. 23513	(757) 852-4500	64.4% Black

TUSKEGEE UNIVERSITY

The following schools were identified by Harrison Orr (UA).

Middle Schools:

Tuskegee Institute	1809 Franklin Rd. Tuskegee, AL. 36083	(334) 727-2580

High Schools:

Booker T. Washington	3803 W. Martin Luther King Hwy. Tuskegee, AL. 36083	(334) 727-0073
Notasulga	500 E. Main St. Notasulga, AL. 36866	(334) 724-1240

COLUMBIA UNIVERSITY

The following schools were identified by Harrison Orr (UA).

Middle Schools:

Democracy Prep Charter	207 W. 133rd St. New York, NY. 10030	(212) 283-1672
Democracy Prep Harlem	222 W. 134th St. New York, NY. 10030	(212) 281-1248

High Schools:

Manhattan Center for Science and Math	280 Pleasant Ave. New York, NY. 10029	(212) 876-4639
Democracy Prep Charter	207 W. 133rd St. New York, NY. 10030	(212) 281-1248
Rice	74 W. 124th St. Harlem, New York. 10027	(212) 369-4100

Other:

Young Women's Leadership School	Grades 6-12	105 E. 106 St. Manhattan, NY. 10029	(212) 289-7593
Future Leaders Institute Charter	Grades K-8	134 W. 122nd New York, NY. 10027	(212) 678-2868
Harbor Science and Arts Charter	Grades 1-8	1 E. 104th St. Suite 603 New York, NY. 10029	(212) 427-2244, ext. 627
Harlem Village Academy Charter	Grades 5-11	244 W. 144th St. New York, NY.	
Thurgood Marshall		200-214 W. 135th St. New York, NY. 10030	(212) 283-8055

UNIVERSITY OF ARIZONA

The following schools were identified by Victoria Tulk (UA).

Elementary Schools:

Sam Hughes Elementary School	700 North Wilson Avenue, Tucson, AZ	(520) 232-7400
Roskruge Bilingual School K-8	501 East 6th Street, Tucson, AZ	(520) 225-2900
International School of Tucson	1701 East Seneca Street, Tucson, AZ	(520) 406-0552
Safford Elimentary and Magnet Middle School	200 East 13th Street, Tucson, AZ	(520) 225-3000
Presidio School	1695 East Fort Lowell Road, Tucson, AZ	(520) 881-5222
Menlo Park Elementary School	1100 West Fresno Street, Tucson, AZ	(520) 225-2100

Middle Schools:

Mansfeld Middle School	1300 East 6th Street, Tucson, AZ	(520) 225-1800
Ha:san Middle School	1333 East 10th Street, Tucson, AZ	(520) 882-8826
Imago Dei Middle School	55 North 6th Avenue, Tucson, AZ	(520) 882-4008
Doolen Middle School	2400 North Country Club Road, Tucson, AZ	(520) 232-6900
Apollo Middle School	265 West Nebraska Street, Tucson, AZ	(520) 545-4500
Baboquivari Middle School	111 W. Main, Sells, AZ	(520) 383-6800
Sierra Middle School	5801 South Del Moral Boulevard, Tucson, AZ	(520) 545-4800
Wade Carpenter Middle School	595 West Kino Street, Nogales, AZ	(520) 287-0820
Wakefield Middle School	101 W. 44th St. Tucson, AZ 85704	(520) 225-3800

High Schools:

Tucson High Magnet School	400 North 2nd Avenue, Tucson, AZ	(520) 225-5000
Salpointe Catholic High School	1545 East Copper Street, Tucson, AZ	(520) 327-6581
Edge High School - Himmel Park	2555 East 1st Street, Tucson, AZ	(520) 881-1389
City High School	48 East Pennington Street, Tucson, AZ	(520) 623-7223
Amphitheater High School	125 West Yavapai Road, Tucson, AZ	(520) 696-5340
Presidio School	1695 East Fort Lowell Road, Tucson, AZ	(520) 881-5222
Catalina Magnet High School	3645 East Pima Street, Tucson, AZ	(520) 232-8400
Flowing Wells High School	3725 N. Flowing Wells Road Tucson, Arizona 85705	(520) 696-8000
Catalina Foothills High School	4300 East Sunrise Drive, Catalina Foothills, AZ	(520) 209-8300
Nogales High School	1905 North Apache Boulevard, Nogales, AZ	(520) 377-2021
Desert View High School	4101 East Valencia Road, Tucson, AZ	(520) 545-5100
Rincon High School	422 North Arcadia Avenue, Tucson, AZ	(520) 232-5600
Santa Rita High School	3951 South Pantano Road, Tucson, AZ	(520) 731-7500
Sahuarita High School	350 West Sahuarita Road #9, Sahuarita, AZ	(520) 625-3502
Sunnyside High School	1710 East Bilby Road, Tucson, AZ	(520) 791-5167