BRUCE MUSEUM
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The Bruce Museum of Arts and Science Education Department Presents: Educator Guide

Light and Color

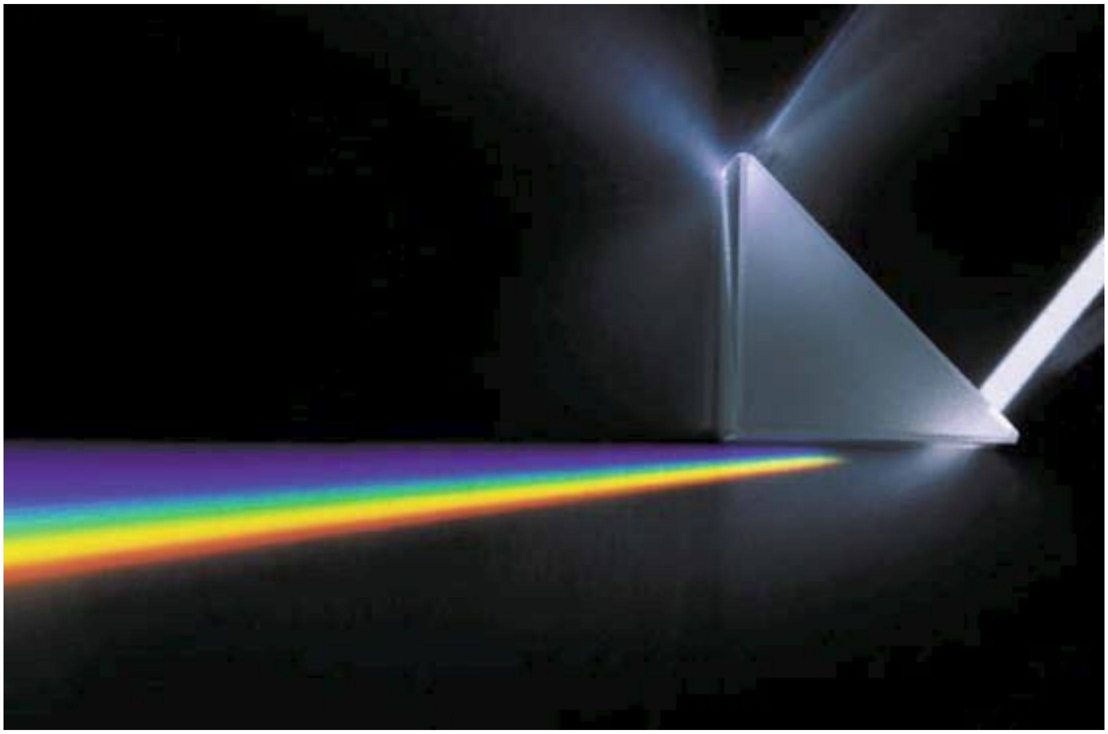


Image from www.student.britannica.com

The Bruce Museum of Arts and Science Education Department develops Educator Guides to provide detailed information on field trip planning, alignment with Connecticut State Goals and Learning Standards and New York Education Standards, as well as suggested hands-on classroom activities to do before, during, and after your visit to the Museum.

Teacher Notes:

This educator's guide is separated into eight parts:

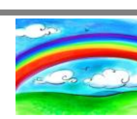
- Exhibition Guide
- Curriculum Connections
- Teacher and Student Resources
- Games and Puzzles
- Activities
- Vocabulary
- How to schedule your Museum visits
- Education Staff List

Students explore properties of light, refraction, diffraction, iridescence and chromatography through demonstration and hands-on, minds-on experiments. Man-made and natural specimens from the Museum's collection are provided as examples to reinforce learned concepts.

School programs are inquiry based and promote critical thinking, written, and oral expression. They feature hands-on-learning activities using objects from Museum collections and exhibitions. Many are interdisciplinary and address various learning styles.

For Brucemobile program information contact Sheean Haley, Manager of Outreach Education at 203-869-6786 Ext. 323 or by email shaley@brucemuseum.org.

For reservations contact Anne Burns at 203-869-6786 Ext. 338 or by email anneburns@brucemuseum.org



Exhibition Guide:

Light:
Light, or visible light, is electromagnetic radiation of a wavelength that is visible to the human eye (about 400–700 nm).

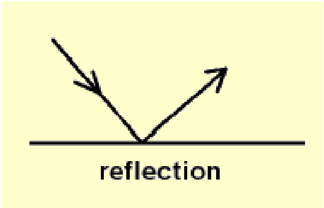
Light Sources:
There are many sources of light. The most common light sources are thermal; these include sunlight (the radiation emitted by the Sun and is in the visible region of the electromagnetic spectrum), incandescent light bulbs, and fire. Certain chemicals produce visible radiation by chemiluminescence (e.g., glow sticks or light sticks). In living things, this process is called bioluminescence (e.g., fireflies, glowworms, and plankton). Certain substances produce light when they are illuminated by more energetic radiation, a process known as fluorescence. This is used in fluorescent lights. Some substances emit light slowly after excitation by more energetic radiation. This is known as phosphorescence.

Speed of Light:
The speed of light in a vacuum is about 186,000 miles per second. The speed of light varies depending upon the medium in which it is traveling. The speed of light in water is 140,000 miles per second, and the speed of light in glass is 124,000 miles per second. It takes 8 minutes for light from the sun to reach Earth.

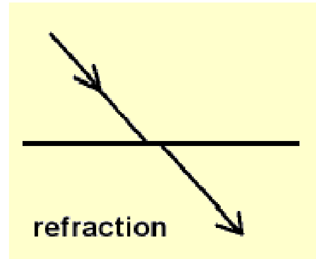
The Spectrum:
A spectrum of visible light refers to those electromagnetic waves which are visible to the human eye. Looking at light through a prism separates visible light into its colors according to wavelength. Violet has the shortest wavelength and red has the longest wavelength of visible light. The colors in order are violet, blue, green, yellow, orange, red (or, in reverse, ROYGBIV). As the wavelengths get bigger below the red visible light they become infrared, microwave, and radio. As the wavelengths get smaller above violet light, they become ultra-violet, x-ray, and gamma ray.

Reflection, Refraction, and Diffraction:

Light reflection is the change in direction of a wave front at an interface between two different media so that the wave front returns into the medium from which it originated. Reflection of light can be mirror-like or diffuse depending on the nature of the interface. A mirror provides the most common model for light reflection. It is also possible for reflection to occur from the surface of transparent media, such as water or glass.

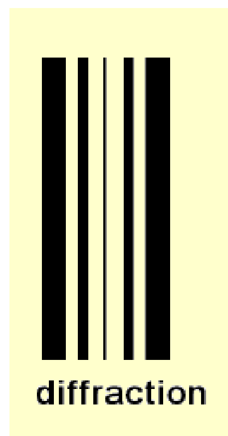


Refraction is the change in direction of a wave due to a change in its speed. This is most commonly seen when a wave passes from one medium to another. Refraction of light is the most commonly seen example, but any type of wave can refract when it interacts with a medium, for example when sound waves pass from one medium into another or when water waves move into water of a different depth.



A sun dog, or "mock" sun, is an atmospheric optical phenomenon produced by the refraction of sunlight by small ice crystal in clouds (Photo from www.nws.noaa.gov)

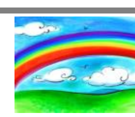
Diffraction is the slight bending of light as it passes around the edge of an object. The amount of bending depends on the relative size of the wavelength of light to the size of the opening. If the opening is much larger than the light's wavelength, the bending will be almost unnoticeable. However, if the two are closer in size or equal, the amount of bending is considerable, and easily seen with the naked eye.



In the atmosphere, diffracted light is actually bent around atmospheric particles -- most commonly, the atmospheric particles are tiny water droplets found in clouds. Diffracted light can produce fringes of light, dark or colored bands. An optical effect that results from the diffraction of light is the silver lining sometimes found around the edges of clouds or coronas surrounding the sun or moon. The illustration above shows how light (from either the sun or the moon) is bent around small droplets in the cloud.

Color and Vision:

Color vision is the ability of an organism or machine to distinguish objects based on the wavelengths of the light they reflect or emit. The nervous system derives color by comparing the responses to light from the several types of photoreceptors, called rods and cones, in the eye. The cone photoreceptors are sensitive to different portions of the visible spectrum. For humans, the visible spectrum ranges approximately from 400 to 700 nm, and there are normally three types of cones. A banana is yellow not because it emits yellow light.



Rather, it simply absorbs all the frequencies of vis ible light shining on it except for a group of frequencies that is perceived as yellow, which are reflected. A banana is perceived to be yellow only because the human eye can distinguish between different wavelengths.

Why is the ocean blue? Water is blue because it selectively absorbs light in the red part of its visible spectrum. Most of the energy, though not all, from the wavelengths in the green region above 550 nm, through the yellow, orange and red wavelengths, is absorbed. Therefore only the blue and blue-green wavelengths remain significantly unabsorbed. The unabsorbed rays of light penetrate deeper into the water column than any of the absorbed wavelengths, meaning a blue color reflects back at you when you observe the water.

Curriculum Connections:

Connecticut

Greenwich

Grade 3

•Recognize that primary colors of light can be mixed to create other colors.

•Demonstrate that light has a number of properties such as color, brightness, and direction of travel.

•Demonstrate that light can be absorbed, reflected, transmitted, and bent using mirrors and lenses

Grade 4

•Describe how light is absorbed and/or reflected by different surfaces.

•Describe how light absorption and reflection allows us to see shapes and colors of objects.

•Demonstrate that light is a form of energy.

•Recognize that primary colors of light can be mixed to create other colors.

•Recognize that black is the absence of all color and white is all colors combined.

Grade 5

•Recognize that the Sun produces energy in a range of wavelengths within the electromagnetic spectrum.

•Identify evidence that waves can transfer energy between two points.

•Compare and contrast different forms of electromagnetic radiation.

New York

Grade 3

•PI 4 (1.1) Students ask why questions in attempts to seek greater understanding concerning objects and events that they have observed and heard about.

•PI 4 (1.1b) Students will articulate appropriate questions based on observations.

•PI 5 (1.2) Students question the explanations they hear from others and read about, seek clarification and comparing them with their own observations and understanding.

•PI 12 (3.3) Share their findings with others and actively seek their interpretations and ideas.

•PI 12 (3.3a) Explain findings to others, and actively listen to suggestions for possible interpretations and ideas.

•PI 13 (3.4) Students adjust their explanations and understandings of objects and events based on their findings and ideas.

•PI 13 (3.4b) State, orally and in writing any new questions that arise from their investigation.

•PI 69 (3.1b) Matter has properties that can be observed through the senses.

•PI 69 (3.1c) Objects have properties that can be observed, described, and/or measured: reflectiveness of light.

•PI 69 (3.1d) Measurements can be made with standard metric units and nonstandard units.

•PI 71 (4.1) Students describe a variety of forms of energy and the changes that occur in objects when they interact with those forms of energy.
•PI 71 (4.1a) Energy exists in various forms: heat, electric, sound and light.
•PI 71 (4.1d) Energy and matter interact: dark colors may absorb light, light colors may reflect light.

Grade 4
•Same as Grade 3 plus
•PI 71 (4.1g) Interactions with forms of energy can be either helpful or harmful.
•PI 71 (4.2a) Everyday events involve one form of energy being changed to another.

Grade 5
•Same as Grade 4 plus
•PI 213 (4.4) Students observe and describe the properties of light.

Student and Teacher Internet Resources:

- American Museum of Natural History's (AMNH) Ology Site for kids
  http://www.ology.amnh.org/einstein/lightmatterenergy/index.html
- AMNH's exhibition on Einstein
  http://www.amnh.org/exhibitions/einstein/
- The Franklin Institute's Introduction to Light and Color
  http://www.fi.edu/color/
- The Physics Classroom: Light and Color
  http://www.glenbrook.k12.il.us/gbssci/phys/Class/light/lighttoc.html
- Star Light, Star Bright explores the nature of the electromagnetic spectrum.
  http://amazing-space.stsci.edu/light/
- The Tech
  http://www.thetech.org/exhibits_events/online/color/intro/
- Teachers' Lab Explores Light and Color
  http://www.learner.org/teacherslab/science/light/index.html

Games and Puzzles:

- Hangman - http://education.jlab.org/vocabhangman/index.html
- Carmine's Introduction to color -
  http://www.alifetimeofcolor.com/play/color1/color1.html
- Color Discovery - http://imet.csus.edu/imet2/bowmany/webquest/color/

Suggested Reading:

Eyewitness Science: Light by David Burnie

The Optics Book: Fun Experiments with Light, Vision & Color by Shar Levine and Leslie Johnstone

What Do You See and How Do You See It? Exploring Light, Color, and Vision by Patricia Lauber

Bear Shadows by Frank Asch

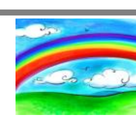
Bouncing and Bending Light by Barbara Taylor

Experiments With Light by Ray Broekel

Light Magic and Other Science Activities About Energy by Trudy Rising and Peter Williams

Shadows and Reflections by Barbara Taylor

Explorabook: A Kids Science Museum in a Book by John Cassidy



Activities:

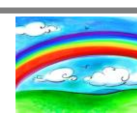
Tasty Color Mixing (ages 4-8)

This activity is a fun and tasty primary color mixing lesson for young students.

Materials:
vanilla cake frosting (store bought or homemade)
red, yellow and blue food coloring
bowls to mix in
popsicle sticks for stirring
paper plates
plain vanilla cookies (optional)
napkins
white paper

What to do:

1) First mix together three different color frostings by adding food coloring to the vanilla icing. This can be done beforehand or during the actual color mixing lesson.
2) Give each student a paper plate and/or 4 cookies.
3) Each student may then add one small spoonful of each color of icing onto one of the paper plates or cookies.
4) Ask your students to predict what color will result when yellow and blue are mixed.
5) The students can then mix small amounts of yellow icing and blue icing together with a popsicle stick and spread the new color on a cookie or paper plate.
6) Ask the students to predict what color will result when blue and red are mixed.
7) The students can then mix small amounts of blue icing and red icing together with a popsicle stick and spread the new color on a cookie or paper plate.
8) Ask the students to predict what color will result when red and yellow are mixed.
9) Students can then mix small amounts of red icing and yellow icing together with a popsicle stick and spread the new color on a cookie or paper plate.
10) Talk about these new findings and discuss color mixing.
11) Draw a color wheel on a large piece of paper at the front of the classroom or on the chalkboard.
12) Finally, have students create their own color wheels on paper using markers, crayons, paint or pencil crayons.



Make a rainbow! (from www.crayola.com for grades 4-6)

Materials:
CDs
Bubble mix and blower
Prisms
Mirror
Water
Plastic pan
Crayons and/or watercolors
Paper

What to do:

1) Discuss rainbows: What colors are in rainbows? Do all rainbows have the same colors? Are the colors always in the same order? What order do you think they are in? Draw rainbows-based on this discussion.
2) Look for natural rainbows, which occur whenever white light is split into the spectrum. Rainbows can form on CDs, soap bubbles, rain drops, fish tanks, and glass as light hits them. Although the sun's rays appear colorless, the rays contain all the colors of the rainbow mixed together. This mixture is known as white light. When white light strikes a white crayon, it appears white because the crayon absorbs no color and reflects all colors equally. A black crayon absorbs all colors equally and reflects none, so it looks black. Artists consider black a color, but scientists do not, because black is the absence of all color. Create black and white designs with crayons or watercolors and discuss the reflection and absorption of colors.
3) Create rainbows, indoors or outside, using a light source such as the sun, and a prism or mirror and water. Record each experiment with drawings of the objects and the spectrum created.
    - To use a prism, hold it between the light source and a plain surface such as a ceiling, wall, or white paper.
    - To use a mirror and water to create a rainbow, place a clear shallow glass or plastic pan in sunlight. Fill the container with water. Rest the mirror on the bottom of the pan, with its top edge leaning out of the water. Light will be bent (refracted) and separate into colors as it enters the water. As the light leaves the water, it will bend again and further separate the colors, making the spectrum more visible on a plain surface.
4) Compare rainbows drawn in step 1 with those represented during the experiments in step 3. How are they similar? How are they different?
5) Research the science of rainbows. Each of the colors in white light bends at a slightly different angle because it has a different wave length. Colors split into the same spectrum every time. Red has the longest wave length and violet the shortest. All other rainbow colors fall in between, in a

definite order-ROY G BIV for red, orange, yellow, green, blue, indigo, and violet.

6) Draw colorful wavelengths to portray their relative sizes. Ultraviolet has an even shorter wavelength than violet. Humans cannot see it, but some birds and bees can.

The Color of Light (http://sln.fi.edu/tfi/activity/physics/op-3.html for grades 4-6)

Ask your students what color they think light is. A silly question? Sunlight or light from a lamp may look "white" but it is really made up of different colors. Red, blue, and green are the primary colors of light. That means you can make any color from combinations of these three. We see an object in a certain color because that color is reflected by the object, while other colors are absorbed.

Materials:
3 big flashlights
pieces of red, blue, and green cellophane paper
tape
30 cm white card
white toy or ornament

What to do:

1) Tape one piece of cellophane over the bulb end of each flashlight.

2) In a dark room, turn on the flashlights.

3) Shine the red and green flashlights on to the white card. What happens? (You make the color yellow.) Try mixing the blue and green lights. (You get cyan.) Now mix the blue and red lights. (You get magenta.)

4) Put the white toy in the center of the card and shine the three flashlights on it. Have the students circle around the toy to see it in different colors.

5) Ask the students what color you will get if you shine all three lights on the white card at the same time. (You get white. White light is made up of red, blue, and green. These are called the primary colors. To get black, you would have mixed colored paints, not lights.)

Vocabulary List:

Diffraction – the effect caused by passing light through a row of narrow openings. This splits up the light into the colors of the spectrum.

Hue - the shade or tint of a color

Incandescent -an electric lamp in which a wire is heated to glow and produce light

Infrared - invisible radiation wavelengths longer than red in the visible spectrum

Light year - the distance that light travels during one Earth year

Microwaves - electromagnetic waves whose wavelengths are longer than infrared, but shorter than short-wave radio waves

Opaque - does not permit the passage of light

Primary color – one of the three colors of paint or light that can be mixed to make any other color. The primary colors of light are red, green and blue. The primary colors of paint are red, yellow and blue.

Prism – a solid shape made of glass or another transparent material, which has equal and parallel ends (often triangular) and sides with parallel edges.

Rainbow - optical illusions and meteorological phenomena that cause a spectrum of light to appear in the sky when the Sun shines onto droplets of moisture in the Earth's atmosphere. They take the form of a multicolored arc, with red on the outer part of the arch and violet on the inner section of the arch.

Reflection – the bouncing back of rays of light from a surface.

Refraction - the turning or bending of a wave as it passes from one medium to another of different density

Spectrum – the band of colors that makes up white light. These are the colors we see in a rainbow – red, orange, yellow, green, blue, indigo, and violet.

Translucent - allows light to pass but not clearly

Wavelenghth - the distance between repeating units of a propagating wave of a given frequency. It is commonly designated by the Greek letter lambda (λ). Visible light ranges from deep red, roughly 700 nm, to violet, roughly 400 nm

White light – light from the sun or an artificial source, such as an electric light bulb, which looks white but is in fact made up of the colors of the spectrum

Gamma rays – light rays with the shortest wavelengths, < 0.001 nm (about the size of an atomic nucleus). This is the highest frequency and most energetic region of the electromagnetic spectrum. Gamma rays can result from nuclear reactions taking place in objects such as pulsars, quasars, and black holes.

X-rays - range in wavelength from 0.001 - 10 nm (about the size of an atom). They are generated, for example, by superheated gas from exploding stars and quasars, where temperatures are near a million to ten million degrees.

Ultraviolet radiation - wavelengths of 10 - 400 nm (about the size of a virus). Young, hot stars produce a lot of ultraviolet light and bathe interstellar space with this energetic light.

Visible light - covers the range of wavelengths from 400 - 700 nm (from the size of a molecule to a protozoan). Our sun emits the most of its radiation in the visible range, which our eyes perceive as the colors of the rainbow. Our eyes are sensitive only to this small portion of the electromagnetic spectrum.

Radio waves - longer than 1 mm. Since these are the longest waves, they have the lowest energy and are associated with the lowest temperatures. Radio wavelengths are found everywhere: in the background radiation of the universe, in interstellar clouds, and in the cool remnants supernova explosions, to name a few. Radio stations use radio wavelengths of electromagnetic radiation to send signals that our radios then translate into sound.

How to schedule your museum visits

- Adult and school groups of 8 or more require advance reservations and are subject to a special group fee.
- Museum-Based School programs are available Tuesday through Friday at 10:00 am, 11:15 am, and 1:00 pm
- After-School Museum-Based programs are available Tuesday through Friday, last one hour, and start no later than 4:00 pm.
- The Bruce Museum is accessible to individuals with disabilities.
- Call Bruce Museum Reservations Manager, Anne Burns, at 203-869-6786 ext.338. You may leave a voicemail message at this number at any time. Please leave a choice of times to return your call.
- **Fees**
  A confirmation/invoice will be mailed four weeks prior to the program. Pre-payment is preferred, however, Museum programs may be paid on day of visit. Payment is by check only, payable to Bruce Museum, Inc.
  Museum-Based Programs: $45 per program.
- **Scholarships**
  Thanks to the generosity of our corporate members and sponsors, scholarships are available under special circumstances. Please contact the Museum for more information.
- **Cancellations**
  There is a $15 charge if cancellation is less than two weeks in advance of the scheduled program.
- **No Eating Facilities are available at the Museum**
  In case of bad weather, classes will be permitted to eat in the Education Workshop if they reserve the room in advance.
- **Class Size**
  In order to maintain quality education, classes are limited to 25 students. Pre-school class size is limited to 20 students.
- **Supervision: REQUIRED for all programs**
  Museum visit: 1 adult for every 5 children, to accompany the children at all times.
  Self-guided tours: If you would like your class to tour the rest of the Museum before or after the scheduled program, you must tell us when you make your reservation to avoid conflict with other groups.
  Nametags: Help to personalize program and enhance student behavior.
- **Conduct**
  In order to enhance everyone's enjoyment of the Museum, please go over these rules with your students in advance:
    - Please do not run in the Museum.
    - Please talk in quiet voices.
    - Please do not touch paintings or objects

Special requests or curriculum needs
All of the programs are flexible and can be adapted to audiences with special needs or to your curriculum objectives. Please discuss with the Museum Education staff in advance.

Education Department Staff List

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