SCIENCE of art
MUSEUM OF GLASS

Curriculum
Art of Light

Dear Educator,

Thank you for booking a Science of Art teaching artist visit and tour with the Museum of Glass. We look forward to working with you and your class!

This learning process is designed to inspire you and your students to think deeply about connections between art and science in your classroom, in the museum, and beyond.

A pre-tour classroom presentation by a museum art educator will pose questions and introduce concepts that will help prepare your students for their Science of Art museum experience. This packet also provides corresponding art and science information as a supporting resource.

Post-tour assessment strategies are provided to check for and validate student understanding of art and science concepts, processes and interrelationships explored through this program.

Along with this packet, we have extensive information on our website about glass blowing and working with hot glass. Visit **museumofglass.org/education**. There are several lessons and interactivities about many glass-related topics. In the Virtual Hot Shop your students will get a taste for glass blowing while online. Participants walk through the process step-by-step until they get a finished work of art! Along the way they can also choose to read more and view video clips of the process live.

Table of Contents

EALRs & GLEs

Science

1.1 Understand how properties are used to identify, describe, and categorize

substances, materials, and objects and how characteristics are used to categorize living things.

1.2 Know and apply scientific concepts and principles to understand the properties, structures, and changes in physical systems.

1.3 Understand how interactions within and among systems cause changes in matter and energy.

3.1 Apply knowledge and skills of science and technology to design solutions to human problems or meet challenges.

3.2 Analyze how science and technology are human endeavors, interrelated to each other, society, the workplace, and the environment.

The Arts

1.3 Apply audience skills in a variety of arts settings and performances.

2.1 Apply a creative process.

2.3 Apply a responding process to an arts presentation: engage actively and purposefully, describe what is seen and/or heard, analyze how the elements are arranged and organized, interpret based on descriptive properties, evaluate using supportive evidence and criteria.

3.3 Develop personal aesthetic criteria to communicate artistic choices.

4.2 Demonstrate and analyze the connection between art and other content areas.

4.4 Understand that the arts shape and reflect culture and history.

Before

Your Museum Visit

Essential questions and concepts will be introduced by our Art Educator in your classroom.

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Art of Light

Why is light an essential component of visual art?

We see because light enters our eyes and stimulates impulses that inform our brain. The frequency and amount of light are determined by the source of light, the materials that transmit the light and the surfaces that reflect light. Artists manipulate these sources, materials and surfaces to shape the light that enters our eyes. Our brain also plays a major role in processing and interpreting the impulses sent to the brain from our eyes.

What are some of the ways that light interacts with glass?

Glass is a material that interacts in a myriad of ways with light. It can ***transmit, absorb*** or ***reflect*** light. It can also ***refract***, or ***diffract*** light in ways that change the color and quality of the light as well as shape the image received by the brain. The artists featured in the Museum's exhibitions use glass to change light in different ways.

Why do artists choose glass as a material for art-making?

Artists choose a ***creative process*** or art material because it has the potential to communicate
specific ideas or has certain aesthetic qualities. Understanding the science of light helps us to better appreciate the way the artists use glass to shape the images we see. Art reveals and enhances the characteristics of light.

- Science GLE 1.1.3 Wave behaviors: Understand wave behaviors, including reflection, refraction, transmission and absorption
  Experience, measure, and describe the motion of light as light bounces off and/ or passes through an object (grade 4)

  Describe the behavior of light waves when light interacts with transparent, translucent, and opaque substances (grade 8)

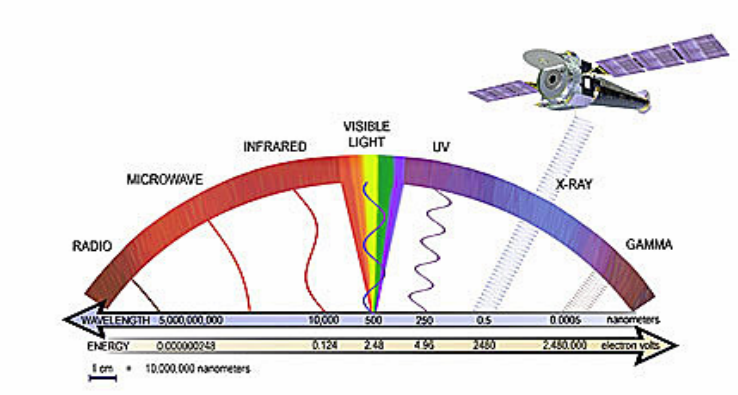
- Art EALR 2.1 Applies a creative process in the arts
  Conceptualizes the context or purpose
  Gathers information from diverse sources
  Develops ideas and techniques
  Organizes arts elements, forms and/or principles into a creative work
  Reflects for the purpose of elaboration and self evaluation
  Refines work based on feedback, Presents work to others

Light is an electromagnetic wave

Electromagnetic radiation is a form of energy that travels in waves. The range of ***wavelengths***, from radio waves that are miles long to cosmic rays that are shorter than a single atom, is called the electromagnetic spectrum.

Visible light is the range of wavelengths from about 400 to 800 nanometers (4 x 10-7 to 8 x 10-7 meters). The part of the spectrum with wavelengths just longer than visible light is *infrared radiation* (IR) which we can detect as heat. *Ultraviolet radiation* (UV), the part of the ***spectrum*** just above visible light, is higher energy radiation that can cause tissue damage. Bees and some other insects can see ultraviolet light and some reptiles can detect infrared light. The range of electromagnetic radiation we call visible light is specifically visible to humans.

light: the portion of the electromagnetic spectrum (range of waves) visible to the eye



refraction: bending of a light beam that occurs at the boundary between one material/medium or another

diffraction: a light beam bending and spreading out as it moves around an object or through a narrow opening(s)

reflection: rays of light bouncing off a surface

Light exhibits wave characteristics such as ***refraction***, bending upon entering a new medium due to a change in speed, and ***diffraction***, bending around a barrier or through an opening in a barrier. In contrast, matter does not refract or diffract. Light rays also ***reflect***: bounce off of surfaces.

Light waves have a frequency as well as a wavelength. The frequency of visible light is detected by the eye as color. The longest wavelengths (lowest frequencies) are red and the shortest are violet. ***White light*** is composed of green, red and blue light. The colors of the spectrum can be seen when *white light* is dispersed through a prism or when light is diffracted such as in a CD or when viewed through diffraction grating a piece of glass or plastic with parallel slots or lines that break white light into the color spectrum.

white light: light from the sun or an artificial source—it appears white but is composed of all of the colors of the visible light spectrum.

How does the light interact with art made of glass? How does the amount or kind of light change visual effects?

Investigate the frequency and amount of light around the school. Does the gym have natural or artificial light, is it darker or brighter in the cafeteria compared to the classroom and library. Why?

An object that emits light, such as a light bulb, the sun, a star, a glowing wire or a fire, is called a ***luminous body.*** The type of radiation that is emitted, infrared or visible light, depends upon the frequency of the vibrating charged particles producing the waves. The sun gives off radiation over the entire spectrum whereas a light bulb emits radiation from infrared to green or blue light in the visible spectrum.

An ***illuminated body,*** on the other hand, reflects light. The moon, the earth and a white piece of paper are all examples of illuminated bodies. Luminous bodies are not transparent; light is emanating from the object rather than traveling through it. For example, neon gas is normally transparent but can be heated until it glows. At that point, it is no longer transparent. Molten glass is another luminous body that can be transparent when it cools.

transparent: a material that transmits light in straight lines without distorting images

translucent: a material that transmits light in diffused directions distorting its path

opaque: a material that absorbs or reflects light, not allowing light to pass through it

Transmission of light

Light is transmitted through a transparent object because the frequency of the light waves does not match the frequency of the atoms in the transparent material. When light shines on a ***transparent*** object, such as clear glass, the energy of the wave is passed from atom to atom inside the object and emerges on the opposite side without losing much energy although the speed of light slows in the material.

The color of an ***opaque*** object depends upon the color of light reflected and the color of a transparent object depends upon the color of light transmitted. Clear glass, for example, transmits all the colors of ***white light*** equally well where as red glass only transmits red light. Colored filters behave the same way; a blue filter transmits blue light and absorbs red and green light.

Students Engage!

Find examples of transparent, translucent and opaque areas in art made of glass

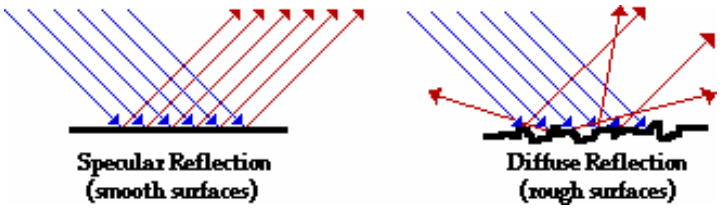
Transparent objects are all around us, from windows, eye glasses, and bottles but do we really notice them? Chart the transparent objects that you encounter on a given day or week. Take notice of translucent and opaque objects as well. Do you notice a pattern? The results may be surprising!

Reflection

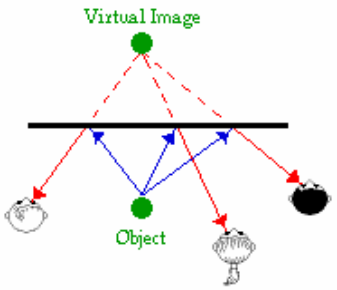
It is possible for us to see objects because light reflects from their surfaces. When the surface is rough, light is reflected in many different directions. When the surface is smooth, light is reflected in the same direction.

Law of Reflection: the angle at which the light reflects off a surface equals the angle at which it strikes a surface

When light rays hit a plane (flat) mirror they reflect at angles that equal their ***angle of incidence.*** This is called the ***Law of Reflection***. When the light is reflected from an object and then from the mirror, an image is formed where the light rays appear to *converge*, behind the mirror and as far away from the mirror as the object is from the mirror. Think of calm, smooth water versus water that has wind and waves: what happens to the reflection?



Concave and convex mirrors bend light as it reflects from a curved surface. Light rays either ***converge*** to a ***focal point*** as in a ***concave*** (*converging*) mirror or ***diverge*** from the mirror as in a ***convex*** *(diverging*) mirror. For objects placed beyond the focal point of a concave mirror, the images produced are inverted. They are called ***real images*** because they can be projected on a screen. For objects placed between the focal point and the mirror, the images are magnified and upright.



They are called ***virtual images*** because they cannot be projected on a screen. Like the images from a plane mirror, they form behind the mirror where the light rays appear to converge. Convex mirrors only form virtual images that are always smaller than the object. For this reason, they are often used in stores or on cars to provide a compact view of a much larger area.

Classroom Activity: Bouncing a Light Beam

When light hits an opaque, shiny surface, it is reflected. The rule in science regarding reflection of waves (including light) is that the angle at which the wave strikes the barrier is the same as the angle at which the wave is reflected. For example, light hitting a flat, plane mirror at 90° will be reflected back at 90°. This rule can be used to predict where a beam of light reflected from a mirror will end up.

This same rule, called the ***Law of Reflection***, also governs where light reflected from a curved mirror will end up. When the reflective surface is convex, such as the underside of a metal spoon, light will reflect in all directions away from the surface. Images seen in convex mirror are smaller than the object, right side up, and cannot be projected onto a screen. We call them virtual images.

When the surface is concave, such as the inside of a metal spoon, light can be reflected to a focal point above the center of the spoon. Images from concave mirrors that can be projected onto a screen are called real images. They can be larger or smaller than the object depending upon how far the object is from the mirror and are upside down. Concave mirrors can also produce virtual images that are larger than the object such as the images viewed in a magnifying mirror.

Objectives:

To apply the law of reflection to predict the direction of a light beam bounced from plane and curved mirrors.

- To explore how light reflects plane and curved mirrors.
- To determine a rule for how light reflects from a plane surface.
- To demonstrate that the same law applies to curved reflective surfaces.

Materials:

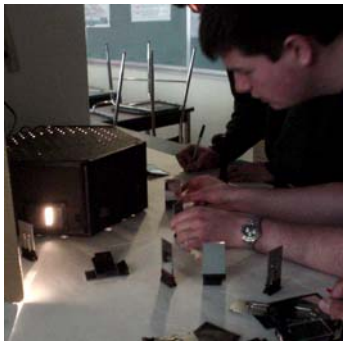
(for group of 2 to 4 students) several small plane mirrors, modeling clay to form stands for the mirrors, several flexible mirrors or spoons (e.g. thick mylar pieces) a small beamed flashlight (mini-maglight), protractors, a darkened room.

Procedures:

1. Challenge students to see how many times they can bounce a light beam using the mirrors. Circulate around the room reporting the maximum number of bounces to "up" the challenge.

2. Turn on the room lights and discuss with students what barriers they encountered when trying to bounce light (light is scattered in each "bounce" so the shorter each pathway, the more mirrors can be used). Ask students what rule determines where light shining on a mirror goes (law of reflection). Encourage students to think in terms of angles and introduce a protractor to measure the angle of the incoming light ray and the outgoing ray.

3. Finally, pass out flexible mirrors to the groups and have students explore how light reflects from a curved surface. Encourage students to train a small beam of light onto one side of a mirror that has been bent into a concave curve (as with the inside of a spoon) and follow the reflected beam. Have them do the same with the mirror curved to the outside (as with the outside of a spoon). Discuss their findings. Is the Law of Reflection different for curved mirrors?



To Learn More About Glass Visit:

http://museumofglass.org/education/learn-about-glass/

AND

Try your hand at glassblowing, *virtually*. Learn about the process of taking hot molten glass and creating a work of art. Check out the School by Fire:

http://museumofglass.org/education/virtual-hot-shop/

During

Your Museum Visit

A quick summary of the activities planned for your day at the Museum.

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Museum Visit Activities

During the visit to the Museum of Glass, students will take part in four sessions:

Theater

Introduction: *Fire Gods*: A Short Animated History of Glass

How has science and technology changed art over time?
How does art reflect history and culture?

Exhibition Gallery

Students engage in a guided inquiry process as they tour the exhibition and record findings in a *Reflection Journal*.

How do we know an object is glass?
Why do artists choose to make art using glass?
What do you think the artist is trying to communicate? Why?

Hot Shop

The Museum of Glass hot shop provides visitors the opportunity to watch the process of forming molten glass into functional glass and art objects. Students interact with artists and ask questions.

What processes are shared by art and science?
How are artists and scientists alike?
What do artists need to know about science in order to make art with glass?

Studio

Students use interactive science tools and art materials. Students will work with a regional artist to create a hands-on art work that explores the connections between science and art.

Why do scientists conduct experiments?
Why do artists conduct experiments?
How is a hypothesis similar to an artistic vision?

Theater

Students share Science of Art findings recorded in words and images in their Reflection Journals.

What is the importance of art in our world? What is the role of the artist?
What is the importance of science in our world? What is the role of the scientist?
How does art challenge existent beliefs?
How does science challenge existent beliefs?

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Classroom Assessment

These post-tour classroom assessment strategies are provided to reinforce student understanding of art and science concepts, processes and interrelationships explored through this program.

Reflect and Describe

Name and describe the different ways that light can interact with glass.

Using science vocabulary, describe how light interacted with a work of art that you saw at the museum.

Design and Communicate

Design a glass sculpture or vessel that has opaque, translucent and transparent areas.

Describe how your glass art work will interact with light and what visual effects it will create or ideas it might communicate.

Connect Art and Science

What is the importance of art in our world? What is the role of the artist?
What is the importance of science in our world? What is the role of the scientist?

Why do artists choose to make art using glass?
What processes are shared by art and science?

How are artists and scientists alike?
What do artists need to know about science in order to make art with glass?

How is a hypothesis similar to an artistic vision?

Resources

Glossary, References, Web Links and more...

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Visual Art Glossary:

2-D or two-dimensional: an object that is flat—having height and width

3-D or three-dimensional: an object that has height, width and depth and can be viewed from multiple points of view

abstract: a work of art exaggerating or simplifying real forms that may or may not be recognizable

balance: equalization of elements in a work of art

color: what the eye sees when a wavelength of light is reflected from a surface

contrast: opposite visual arts qualities placed side by side (e.g., light against dark, heavy against light, textured against smooth, etc.) to create visual interest

creative process: The way in which an artist conceptualizes, gathers information, develops skills and techniques, organizes visual elements, reflects, refines and presents a work of art

emphasis: use of contrasts (color, size, shapes) to place greater attention on specific parts of a work of art

form: a three-dimensional object that has height, width and depth

installation: an art work especially arranged and constructed for an exhibit or space—sometimes forming an environment where variables of light, sound and perception of space are manipulated by the artist

line: a mark made with a tool or material across a surface

opaque: a material that absorbs or reflects light, not allowing light to pass through it

pattern: repeating sequence of lines, shapes or colors

relief: a type of sculpture or surface in which forms project from a flat background

rhythm: movement in art created through repetition of elements

sculpture: a three-dimensional work of art

shape: a 2-dimensional enclosed space

space: the area above, below, around, and within a work of art

symmetrical/formal balance: a type of balance that results when both sides of an artwork are the same or mirror one another

technique: methods of working with art materials to create artwork

texture: real or implied tactile characteristics of a surface

translucent: a material that transmits light in diffused directions distorting its path

transparent: a material that transmits light in straight lines without distorting images

unity: wholeness, all elements belonging together in a work of art

value: lightness or darkness of an area of color or tone

variety: diverse elements used together to create visual interest in a work of art

vessel: a container

Science Glossary

color: what the eye sees when a wavelength of light is reflected from a surface

concave mirror: a mirror that reflects light from its inwardly curved surface and produces either inverted, real images or upright, virtual images

cones: the specialized cells in the retina of the eye that are sensitive to color, specifically red, green and blue

convex mirror: a spherical mirror that reflects light from its outer surface and produces virtual, reduced, upright images

diffraction: a light beam bending and spreading out as it moves around an object or through a narrow opening(s)

diffraction grating: a piece of glass or plastic with parallel slots or lines that break white light into the color spectrum

electromagnetic radiation: energy carried through space in the form of waves

focal point: the point where parallel light rays converge or appear to diverge after reflecting from a mirror or refracting from a lens

frequency: in any periodic motion (such as a wave), the number of complete oscillation in a period of time

illuminated: a body that reflects light waves produced by an outside force

image: reproduction of object formed with mirrors or lenses

incident light: light falling on or striking a surface

law of reflection: the angle at which the light reflects off a surface equals the angle at which it strikes a surface

light: the portion of the electromagnetic spectrum (electromagnetic radiation with wavelengths from 400 to 700 nanometers) visible to the eye (stimulates the retina of the eye)

luminous body: An object that emits light, such as a light bulb, the sun, a star, a glowing wire or a fire

opaque: a material that absorbs or reflects light, not allowing light to pass through it

plane mirror: a flat, smooth surface that reflects light rays by regular reflection, not by diffuse reflection—it forms a virtual, erect image the same size as the object and the same distance behind the mirror as the object is in front

prism: a piece of glass that has equal and parallel ends and sides with parallel edges that disperses white light into the full spectrum of colors

real image: an optical image formed when light rays converge and pass through the image, producing an image that can be viewed on paper or projected onto a screen.

reflection: rays of light bouncing off a surface

refraction: the bending of a light beam that occurs at the boundary between one material/medium or another

regular reflection: reflection off a smooth surface, such as a mirror, where light is reflected back to the observer in parallel beams, producing a clear image

retina: the specialized layer of nerve cells in the eye that are stimulated by light energy

spectrum: the band of colors making up white light

translucent: a material that transmits light in diffused directions distorting its path

transparent: a material that transmits light in straight lines without distorting images

virtual image: the point from which light rays appear to diverge without actually doing so

wave: a rhythmic disturbance that carries energy through matter or space

wavelength: the shortest distance between points where the wave pattern repeats itself

white light: light from the sun or an artificial source—it appears white but is composed of all of the colors of the spectrum

Glassblowing Glossary

annealer: an insulated box, similar to an electric kiln, designed to cool glass slowly at a specified rate. If hot glass is cooled too quickly, the stress on the glass will cause it to be unstable and through time cause it to break.

batch: a mixture of the basic components of glass (silica, soda, or potash and lime). When heated to its melting point, approximately 2400°F, the mixture becomes glass.

block: a wooden tool that is kept wet and used to shape glass

blowpipe: an iron or stainless steel tube shaped for blowing glass

casting: the process of pouring hot glass into molds of various materials, the simplest being sand. Casting can also be done from the kiln, where the glass starts in a cold state then melted into plaster/silica molds.

cold shop: a workshop with equipment to grind, polish, engrave and/or cut glass and/or to add surface details to finished glass pieces.

furnace: equipment used for melting batch and keeping glass at a constant temperature. The temperature of the furnace ranges from 2150°F working temperature to 2400°F charging temperature.

fusing: heating pieces of glass until they bond. This process is achieved within an annealer.

gather: also called a dip. The process of collecting molten glass from the furnace on a pipe, punty or gathering iron.

glory hole: a heavily insulated cylinder, kept between 2100°F and 2300°F, which is used to reheat hot glass as it is being formed and manipulated in the Hot Shop.

hot shop: a workshop where molten glass is blown, cast or manipulated.

jacks: bladed tools used by glassblowers to shape molten glass. They come in various shapes and sizes to accommodate the work being made.

marver: a large, flat surface on which hot glass is rolled when it is attached to a blowpipe or punty.

pontil or punty: a metal rod that is used to gather a small amount of hot glass, which is then transferred to the object or used to transfer the object making it possible to work the other end.

slump: heating glass so that it softens and changes shape without becoming molten.

tweezers: tong-like tool used to grab or manipulate hot glass.

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Credits

Science of Art Unit 14 (Art of Light)

Curriculum prepared in partnership with Linda McCone, formerly of Wilson High School, and Meredith Essex, local art educator.

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