Lesson Plans
The Science of Light

The learning activities in this Lesson will help students prepare to complete the GE Lighting Audit for their school or home as they learn about the nature of light.

Overview and Background

This Lesson comprises five learning activities.

What is Light? is a Read About that discusses the spectrum of electromagnetic radiation including visible light. Students learn that light is made up of photons, which can appear to be sometimes like waves and sometimes like particles. For more information on related scientific concepts, see More Background included in this Lesson Plan.

Separating Light with a Prism is a Hands-on activity in which students use readily-available materials to explore bending visible light and observe its component colors.

In Making a Pinhole Camera*,* another Hands-on activity, students learn that the eye works like a camera.

Reflecting Light and Bending Light are two Experiments your students can conduct with minimal materials, independently, or in small groups.

Students Will Learn

- that EM spectrum is a range of transmitted energy, of which visible light is a part.
- that light moves in waves, as well as in bundles of energy called photons.
- that white light is a combination of all colors.
- that reflection bends, or bounces, light backward.
- that refraction bends and separates light.
- that the eye sees images upside down.

Sequence and Pacing

The chart below suggests options for incorporating the activities into your schedule.

Activity	Class Periods Needed to Complete	Teaching Approaches to Consider	Features

<table>
<tr><td>1. What Is Light?</td><td>one</td><td>Independent reading

Guided reading</td><td>Before Reading, During Reading, Vocabulary, and After Reading questions

Animation: The Visible Spectrum</td></tr>
<tr><td colspan="4">Teaching Ideas

Review student's KWL charts to identify misconceptions student's have about light and its properties.
Make a T-chart on the board, labeling the sides "Light as Waves" and "Light as Particles." Have students suggest details about light, demonstrating each concept. You might organize small groups to brainstorm ideas for each side. Compile the ideas into one chart to complete the lesson.</td></tr>
<tr><td>Activity</td><td>Class Periods Needed to Complete</td><td>Teaching Approaches to Consider</td><td>Features</td></tr>
<tr><td>2. Separating Light with a Prism</td><td>one or two</td><td>Teacher demonstration

Students working in pairs or small groups

Independent work at home</td><td>Sidebar: The Not-So-Blue Jay

Animation: The Visible Spectrum</td></tr>
<tr><td colspan="4">Teaching Ideas

See the student's page for this activity. You might organize small groups to try the different versions suggested. Some can try different light sources with one prism, some can attempt the two-prism set-up, and some can try to create the prismatic effect with common objects.
Give small groups of students bubbles, bubble wands, and a large dish. Have them make rainbows on the walls using them. Why aren't the colors on the bubbles themselves in rainbow order?</td></tr>
<tr><td>Activity</td><td>Class Periods Needed to Complete</td><td>Teaching Approaches to Consider</td><td>Features</td></tr>
<tr><td>3. Making a</td><td>one</td><td>Independent work</td><td>Animation: Inside a</td></tr>
</table>

<table>
<tr><td>Pinhole Camera</td><td></td><td>at school or at home</td><td>Pinhole Camera

Animation: How We See</td></tr>
<tr><td colspan="4">Teaching Ideas

After viewing the two animations linked to the student page for this activity, challenge your students to describe how the eye and the camera are similar and different.
With just a few more materials and a little adult supervision, you can make a pinhole camera with film! Invite students to create one for extra credit. There are plenty of online sources with complete instructions. Here are a few links if you want to check them out:
http://www.nh.ultranet.com/~stewoody/
http://www.mckendree.edu/edu-tech/plans/science/m16.html
http://www.smithsonianmag.si.edu/journeys/
http://www.accessart.org.uk/photograph/pinhole%20camera.pdf</td></tr>
<tr><td>Activity</td><td>Class Periods Needed to Complete</td><td>Teaching Approaches to Consider</td><td>Features</td></tr>
<tr><td>4. Reflecting Light</td><td>one</td><td>Teacher demonstration

Students working in pairs or small groups</td><td>Line Graph: Temperature Changes Over Time</td></tr>
<tr><td colspan="4">Teaching Ideas

Some demonstrations are difficult for a large group to see. Consider having stations and parent demonstrators or organizing the experiments in "circuits" around the room.
Have students complete a reflecting experiment. Cut a small hole in a sheet of cardstock and tape a comb across the hole. In a darkened room, place the card in front of the torch, so that narrow beams of light come through the teeth of the comb. Hold a mirror in the beams of light so that it reflects the light. Move the mirror to a different angle. Predict what will happen to the angle of the reflected light rays as the light hits the mirror.
Have students describe a mirror image of themselves. What size are you in the mirror? Where is your right side in the mirror? How does the reflection of light cause a reverse image?</td></tr>
<tr><td>Activity</td><td>Class Periods</td><td>Teaching</td><td>Features</td></tr>
</table>

	Needed to Complete	Approaches to Consider	
5. Bending Light	one	Teacher demonstration Students working in pairs or small groups	Sidebar: The Archerfish

Teaching Ideas

A container of water with a few drops of milk makes a great medium to visualize the refraction of a laser pointer beam. It will also make the point that, as the beam passes out of the container and into the air, it bends again as seen by the position of the laser dot on the wall. Does the angle of refraction get even larger, or does it correct itself when it leaves the jar?
A simple spoon can serve as a concave/convex mirror for further investigation of refraction. The scoop of the spoon is concave, the back, convex. How does a concave mirror distort, or change, the image? Predict how the convex mirror will distort the image.
Use a large fish tank of clean water to create a refraction game. Drop several waterproof items in the tank and have students retrieve each item. Explain that it will be harder than it sounds because the item will not be where their eyes tell them it will be. Have students explain why, using the term refraction.
Teach students a standard magic trick – the disappearing penny. Place a penny under a clear drinking glass. Pour water into the glass. The penny will appear to vanish when looking through the side of the glass. (It is still visible from above the glass.) Invite students to explain how the trick works using the term refraction.

More Background

Light Is Energy

Visible light is the part of the electromagnetic spectrum that is visible to the human eye. The EM spectrum is the range of different types of radiated, or transmitted, energy. Besides visible light, other parts of the EM spectrum include x-rays, UV rays, and infared.

(see http://amazing-space.stsci.edu/light/ems-frames.html)

Scientists have learned much about the nature of light in the past few centuries. We know that white light is actually made of all the colors together. A prism can be used to separate white light into the rainbow that forms it. Colors can be seen well in white light because an object that is red, for example, absorbs all colors except red, which it reflects and the eye detects. Objects that absorb all light appear black.

Light can be both a cause and an effect, a producer and a product. For example, extreme heat can create light, such as in a chemical reaction. And light causes photosynthesis, causing plants to grow. Photoconductors produce electricity, while electricity can heat a glass bulb filament enough to create light.

Some ways that light behaves can be explained by the fact that it is made of particles. Other behaviors are better explained when thinking of light as waves.

Light as Waves

In 1690, Dutch scientist Christian Huygens tried to prove that light comes in waves. Soon afterward, Sir Isaac Newton experimented proving that light comes in particles. At that time, the scientific world believed that the same energy could not coexist as both waves and particles. Therefore, most scientists dismissed Huygens' theories.

More than 100 years later, however, several scientists did more to prove Huygens' idea. They used different experiments to show light moving in waves. One property of light proving the wave theory is refraction, or how light moves around an object. Some experiments illustrated that light moves much like waves in water do.

As in water or sound waves, light waves have specific properties. Waves have crests (high points) and troughs (low points). A wavelength, measured from crest to crest, determines the color of the light. Frequency, or the amount of waves going through a fixed point per second, establishes the type of EM wave, such as visible light or radio waves.

Light as Particles

Seemingly disproving the wave theory, Sir Isaac Newton stated in 1704 that light comes in tiny particles. A respected scientist, Newton used convincing experiments and calculations. In 1905, Albert Einstein upheld Newton's theory by showing that light travels as little bundles of energy he called *photons*. Einstein was able to explain how any EM energy behaves both as a wave and as a stream of photons.

Lesson Plans
The Technology of Light

The learning activities in this Lesson will help students prepare to complete the GE Lighting Auditor for their school or home as they learn about different types of light bulbs and how we light our world.

Overview and Background

This Lesson comprises three learning activities.

Ways We Create Light is a Read About that discusses how incandescent, fluorescent, laser, and LED lights work. For more information on related concepts, see More Background included in this Lesson Plan.

Types of Light Bulbs is a Read About that describes the different types of incandescent, fluorescent, and high-intensity discharge (HID) light bulbs and their uses. For more information on related concepts, see More Background included in this Lesson Plan.

In Completing a Circuit,a Hands-on activity, students learn how to create an electrical circuit using simple materials to light a flashlight bulb.

Students will Learn

to describe different types of lighting, including natural light sources.
that most light bulbs are either incandescent or fluorescent.
to identify types of light bulbs.

Sequence and Pacing

The chart below suggests options for incorporating the activities into your schedule.

Activity	Class Periods Needed to Complete	Teaching Approaches to Consider	Features
1. Ways We Create Light	one or two	Independent reading Guided reading	Before Reading, During Reading, Vocabulary, and After Reading questions

			Animation: Timeline: History of Lighting Animation: Lighting a Scene

Teaching Ideas

Organize small groups of students to research and report to the class on one of the types of man-made or natural light discussed in the article. Have students choose the lighting invention they believe to be the most important. Allow students to state and defend their argument for "The Most Important Lighting Invention."

Activity	Class Periods Needed to Complete	Teaching Approaches to Consider	Features
2. Types of Light Bulbs	one	Independent reading Guided reading	Before Reading, During Reading Vocabulary, and After Reading questions. Photo Feature: Types of Light Bulbs

Teaching Ideas

- Follow up students' reading with a discussion based on their responses to the Before, During, and After.
- Challenge students to describe in writing the lighting in the four scenes in the Lighting Design animation.

Activity	Class Periods Needed to Complete	Teaching Approaches to Consider	Features
3. Completing a Circuit	one or two	Teacher demonstration Small group work in class	Sidebar: Fishy Electricity

		Independent work at home	

Teaching Ideas

Have students create schematic drawings of the circuits they have created. Teach students to use the same materials as in the Hands-on activity to make a parallel circuit and a series circuit. Which is more useful?

More Background

Light Bulbs and Their Uses

The two main types of light bulbs commonly found in indoor situations are incandescent and fluorescent.

Incandescent bulbs are used in most household lamps and light fixtures. Incandescent means to "glow with heat." Incandescent light bulbs consist of a hot wire in a bottle. The wire or filament must be a poor conductor of electricity. That way, it really heats up as electricity tries to go through it. The filament then glows. Interestingly, less than 10 percent of the electricity used actually produces light. The rest is what it takes to heat up the filament.

The filament does not burn up because of the vacuum, the lack of oxygen, in the bulb. The light eventually burns out because of the wear of electric current going through it. As the filament "burns," pieces of it blacken and collect inside the bulb, dimming the bulb.

Halogen bulbs are an unusual incandescent light. Halogen is a type of gas inside the glass. The bulb stays bright because of the "halogen cycle." During the halogen cycle, the filament pieces don't collect in the bulb. Instead, the tungsten filament reacts with the gas, which in turn deposits the tungsten back onto the filament. This process makes the bulb last longer, burn brighter, and stay bright the entire time.

Flourescent

Fluorescent bulbs are generally used indoors for offices, stores, and schools. Fluorescent means to "convert absorbed light into another form of light." The word comes from the mineral fluorspar, which glows from this process. Fluorescent lights work with ballasts and chemicals in the bulb. The ballasts are electrodes, or electrical conductors. The glass tube has a ballast at each end. When switched on, electricity flows to the ballasts, heating them. An electric current passes through the tube in an arc between the ballasts. The heat from the electricity vaporizes drops of mercury in the tube, making them emit ultraviolet light. Ultraviolet light is not visible to the human eye. But it still stimulates the coating of phosphor on the inside of the glass. It is the phosphor that makes the bulb shine in all directions.

Fluorescent bulbs cannot be made as small as incandescent lights can. New developments, however, have helped companies create smaller fluorescent bulbs. These new "compact fluorescents" can be used in most household fixtures that are on for long periods of time. Although the bulbs are more expensive than incandescent bulbs, their efficiency and longer life actually saves the consumer money.

Lesson Plans
The Math of Light

The learning activities in this Lesson will help students prepare to complete the GE Lighting Audit for their school or home as they learn how we measure various properties of lighting and choose the best light bulb for a given lighting need.

Overview and Background

This Lesson comprises three learning activities.

What's Watt: Measuring Light is a Read About that presents the definitions of various terms used in the measurement of light intensity, illuminance, and the energy consumed by light bulbs.

In Inverse Square Law, a Hands-on activity that extends the learning in What's Watt, students work with the mathematics of illuminance to understand that the amount of light that falls on a surface is geometrically related to its distance from the light source.

In How to Read a Light Bulb Package, a Hands-on activity, students compare information about lumens, wattage, and longevity for three different types of light bulbs.

Students Will Learn

- to define watt as energy usage.
- about illuminance.
- how candlepower, candela, and lumens are terms related to light intensity.
- the difference between light bulb wattage and lumens.

Sequence and Pacing

The chart below suggests options for incorporating the activities into your schedule.

Activity	Class Periods Needed to Complete	Teaching Approaches to Consider	Features
1. What's Watt: Measuring Light	one or two	Independent reading Guided reading	Before Reading, During Reading, Vocabulary, and After Reading

<table>
<tr><td></td><td></td><td></td><td>questions

Sidebar: The Photometer</td></tr>
<tr><td colspan="4">Teaching Ideas

As a homework assignment, ask students to list five different places in their homes where incandescent light bulbs are used. These may include a desk lamp, inside a refrigerator, a hallway, a closet, over a bathroom mirror, etc. Have them record the wattage of the light bulb used in each place. Challenge them to compute how many watts of the energy consumed actually results in visible light and how many result in heat.
Have students read aloud their responses to the After Reading question about new things they have learned from reading this article. Further discuss any misconceptions or faulty understandings they may have.</td></tr>
<tr><td>Activity</td><td>Class Periods Needed to Complete</td><td>Teaching Approaches to Consider</td><td>Features</td></tr>
<tr><td>2. Inverse Square Law</td><td>one</td><td>Teacher demonstration

Small group work in class</td><td>Animation: Inverse Square Law

Sidebar: Why is the Inverse Square Law Important to Astronomers?</td></tr>
<tr><td colspan="4">Teaching Ideas

Challenge students to increase the illuminance of a light source by using light or reflective surfaces as opposed to dark surfaces. Have students demonstrate their ideas.
Discuss with students the importance of the Inverse Square Law to astronomers. Who else might use this formula?
Use the set-up for the demonstration to make silhouettes of students. Is there a better place for the student to sit? How can you make the shadow be an exact silhouette?</td></tr>
<tr><td>Activity</td><td>Class Periods Needed to Complete</td><td>Teaching Approaches to Consider</td><td>Features</td></tr>
<tr><td>3. How to Read a Light Bulb Package</td><td>one or two</td><td>Small group work in class</td><td>Photo Feature: Consumer-Friendly Packaging</td></tr>
</table>

		Independent work at home	Packaging Sidebar: Design Your Own Bedroom

Teaching Ideas

Have small groups work together to make bar graphs of their findings. How else could they diagram their research?

Challenge students to write their own advertisement for the most efficient light bulb. The ad could be a poster, a radio spot, or a television commercial. Remind students to use their findings to be persuasive.

Lesson Plans
The History of Light

The learning activities in this Lesson will help students prepare to complete the GE Lighting Auditor for their school or home as they learn about the lives of Thomas Edison and Lewis Latimer, both of whom contributed to the improvement and practicality of the light bulb.

Overview and Background

This Lesson comprises three learning activities.

Thomas Edison's Biography is a Read About that offers an historical view of Edison's life.

Lewis Latimer's Biography is a Read About that describes the life of one of the most influential of Edison's Pioneers, who was a brilliant inventor in his own right.

In Designing a Filament, an Experiment, students recreate one of the investigations that led Edison and Latimer to perfect the tungsten filament.

Students Will Learn

- the historical significance of Thomas Edison and his inventions.
- the historical significance of Lewis Latimer and his inventions.
- the process of inventing.
- how a light bulb works and how it is constructed.

Sequence and Pacing

The chart below suggests options for incorporating the activities into your schedule.

Activity	**Class Periods Needed to Complete**	**Teaching Approaches to Consider**	**Features**
1. Thomas Edison's Biography	one or two	Independent reading Guided reading	Before Reading, During Reading, Vocabulary, and After Reading questions Animation: History

			of Light Timeline Film Clip: The Two Most Important Influences in My Life

Teaching Ideas

Lead a discussion on the influences in Thomas Edison's life that shaped him and shaped his inventions.
What would life be like without Edison's inventions? Challenge students to write a science-fiction story or essay on their speculations. Would someone else have invented something similar? Would life now still be exactly the same?
Have students write a letter to Edison's boyhood schoolteacher to brag about his accomplishment.

Activity	**Class Periods Needed to Complete**	**Teaching Approaches to Consider**	**Features**
2. Lewis Latimer's Biography	one or two	Independent reading Guided reading	Before Reading, During Reading, Vocabulary, and After Reading questions Animation: History of Light Timeline

Teaching Ideas

- Have students work in small groups to create a timeline of Lewis Latimer's life.
- Invite students to debate whether Latimer's life would have been different if he had been born to slavery or if he had not been African American.
- Many seemingly small happenings in Latimer's life led to big events. Have students write cause/effect statements about events in Latimer's life.

Activity	**Class Periods Needed to Complete**	**Teaching Approaches to Consider**	**Features**
3. Designing a Filament	one or two	Teacher demonstration	Part 1: Building a Better Light Bulb

		Supervised small group work in class	Part 2: Creating a Vacuum Part 3: Making a Longer Lasting Light Bulb

Teaching Ideas

Since this experiment involves using a 6-volt battery to create heat and light in filament material, you will want to supervise your students carefully as they perform the steps involved. Complete instructions for the student have not been included at the student's Website page but are provided below at Experiment: Designing a Filament. Read it carefully to understand the simple steps involved. Distribute to students.
Introduce the scientific method to students, then have them use it while conducting experiments. The steps are:

1. state the problem
2. do research
3. make a hypothesis
4. test the hypothesis
5. state a conclusion or revise one of the previous steps

Experiment: Designing a Filament

In 1879, Thomas Edison finally achieved a working light bulb after many hundreds of failures. His greatest challenge was to find a material for the filament that could remain heated for days before burning up. Edison realized early on that, regardless of which material worked best, the filament must be contained in a vacuum.

In this next experiment, you will recreate the efforts of Thomas Edison to develop the incandescent light bulb. Before you begin, you should know that you will likely not have the kind of success that Edison achieved, but knowing that should better prepare you for the challenge of building a working light bulb!

After you have developed the techniques to construct a basic working light bulb, you are then going to be challenged to test a variety of materials for the filament, just as was Edison over the months and years before 1879.

Part 1: Building a Basic Light Bulb

In this activity, you will be creating a partial vacuum in a jar. The better the vacuum, the longer the filament will glow before burning out.

What You Will Need:

A 1 quart jar with tight fitting lid (such as a mayonnaise, peanut butter, or canning jar)
Masking tape
Scissors
A small nail and hammer
Small gauge electrical wire (about 1 meter)
Lamp wire
One 6-volt battery
Birthday candles
Small amount of modeling clay
Stop watch (or a clock with a second hand)

Use the a nail to punch 2 small holes in the lid of the jar, about 5 cm apart. Strip off the insulation from the ends of each wire using a pair of scissors. Run one end of each wire through the lid of the jar, so that they extend to about the middle of jar when the lid is on. Use tape to tightly plug the holes in the jar lid. Attach the end of one wire to one terminal on the 6-volt battery.

Now you need to add the filament. Remove a single strand of wire from lamp wire, about 4 cm long. Wind the wire around the nail to make a coil, noting the number of coils. Then carefully remove the coil from the nail and connect it to the two ends of the wire attached to the lid (this will take some skill). Now, you are ready to test your first light bulb.

For this part of the test, it is best to have one person work the bulb and the other work the stopwatch or wristwatch. The timekeeper should give a countdown (much like a rocket launch), at which time the light bulb operator touches the unattached wire to the remaining battery terminal. Keep contact until the filament burns out, or until 15 seconds have passed. (If your light bulb is too successful, you will drain the battery). How bright did the filament glow? For a more exciting effect, dim the lights in the room for each test.

If the filament glows for more than 15 seconds, run the experiment again, but with progressively shorter filaments. Keep the number of coils in each filament constant. Do you think the shorter filaments will burn shorter or longer? Record the length of each filament and the duration the filament burned on a datasheet. You can prepare a graph showing filament length on the x-axis and duration of the filament on the y-axis. If the longer filaments burn longer, why not make light bulbs with very long filaments? If you are a good observer, you may have the answer. Although longer filaments last longer, they do not glow nearly as brightly. All the energy going into the bulb ends up as heat rather than as light. Can you think of devices in your home that use coils to produce heat rather than light?

Part 2: Creating a Vacuum

In this experiment, you will use a lit candle as a means of creating a vacuum in the jar. How do you think a vacuum will affect the longevity of your filament? Using the data collected in the first experiment, select a filament length that burned for about 5 seconds. Prepare at least 5 of these filaments for use later.

Use the modeling clay to make a base for the birthday candle and place the candle in the jar. Place it off to the side so as not to interfere with the filament. Now, light the candle and quickly, tightly screw the lid on the jar. When the candle goes out, a partial vacuum is created. (How?) Have the timekeeper start keeping time when the bulb is turned on. How long did the filament burn now? Record your results. Repeat the experiment several more times, making certain to keep the shape and the length of each filament constant. How has a vacuum affected the duration of the filament's burn? Now you know why a light bulb makes that loud pop when you drop one!

Part 3: Making a Longer-Lasting Light Bulb

Now that you have perfected the partial vacuum light bulb, you can try different filaments. Before you begin, think about the two desirable qualities in a light bulb. As you learned earlier, the duration of the filament isn't the only quality sought after; the amount of light produced is also critical. Using the procedures developed above, try other materials as filaments. Suggestions include steel wool fibers (you can wind them together to make different thicknesses of filament), thin craft wire, and thinner pieces of copper wire. You can even collect the actual filament from a real light bulb by placing the bulb in a plastic bag, placing the bag under a heavy cloth, then striking the bulb with a hammer. Carefully remove the filament from the bag, taking great care not to cut yourself. The filament and the wire connectors can be cut from the base of the bulb and attached to the wires in your light bulb. How does the real thing compare with your own homemade filaments? The fact is, even the real filament (made of a metal called tungsten) will not last that long without a good vacuum. Record all of your findings as you test each filament.

You might want to prepare a report of your findings to your classmates or prepare a presentation board showing your setup and the results from your tests as graphs or tables. Be sure to include your materials and methods and your conclusions. How good were you at building the better light bulb?