Middle School | *Physical Science*

Waves and Electromagnetic Radiation

Teacher's Guide

BOCES 4 Science

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BOCES 4 Science

Written by teachers and administrators from public school districts within the borders of the NYS Midwest Joint Management Team in conjunction with the BOCES 4 Science Educators

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4/18

Foreword

BOCES 4 Science is a collaboration between four New York State BOCES (Board of Cooperative Educational Services) with in the Midwest Region. This collaborative of science educators came together to respond to the need for instructional resources based on the New York State pK-12 Science Learning Standards (NYSSLS). The research behind the Next Generation Science Standards (NGSS) and the National Research Council (NRC) publication, A Framework for K-12 Science Education is the basis for the NYSSLS and the BOCES 4 science units.

We believe that the future health and well-being of our world depends on scientifically literate people making informed decisions. The development of scientific literacy begins at the earliest grades. Elementary children must have concrete experiences upon which to hook their understanding and new vocabulary – this is especially true in the discipline of science. We embrace the notion that students should experience phenomena and solve real problems to learn about the world. We strive to present lessons and materials that will make high quality science instruction available for all students through cost-effective resources for teachers.

Table of Contents

About this Unit

Overview
This ***Waves and Electromagnetic Radiation unit*** is designed for ***Middle School Grades 6-8***. The unit was originally written to introduce Middle School students to Photonics. The unit has since been re-purposed to more directly address the Middle School physical science standards on waves and electromagnetic radiation. Main topics included in this unit are the behavior of light, behavior of waves, digital and analog communication. The theme of photonics still remains in the unit particularly in the lessons that deal with the laser.

Scheduling
This unit is scheduled to be in the classroom for 10 weeks. There are approximately 25 science instructional sessions in this unit, based on 30-40 minutes each. Adjust your schedule accordingly. Please return the unit promptly or to request an extension, call 585-352-1140.

Materials to Obtain Locally
Some lessons require materials that are NOT supplied in the kit. These materials can be easily obtained by the teacher or the students. Materials that will need to be provided are indicated with an asterisk in the lesson materials list and are also listed below:

Chart paper	Water	Post-it notes
Rulers or meter sticks	Chalk	Hot plate, burner, or frying fan
Penny	Removable tape	Calculator
Pencil	"8 ½ X 14" paper	Blindfold

Three Dimensions
Each of the BOCES 4 Science lessons includes at least one element from each of the three dimensions identified in the New York State Science Learning Standards (NYSSLS). The lesson page identifies the specific elements targeted. The NYSSLS topic page is on page 8 of the Teacher's Guide

Science and Engineering Practices (SEP) – These are the major practices that scientists employ as they investigate and build models of their understanding of the world. They also include key practices used by engineers as they design and build systems.

Disciplinary Core Ideas (DCI) – Selected to represent four major domains: the physical sciences; the life sciences; the earth and space sciences: and engineering technology, and the applications of sciences.

Crosscutting Concepts (CCC) – These big ideas have application across all domains of science and provide one way of linking across the domains of the DCI's. In addition, they link to ideas that are parts of other elementary subjects.

Waves and Electromagnetic Radiation

NYSSLS Shifts in Instruction

It is the intention of BOCES 4 Science that this unit provides lessons that demonstrate the following shifts in instruction:

- **Explaining Phenomena or Designing Solutions to Problems:** The unit focuses on supporting students to make sense of a phenomenon or design solutions to a problem.
- **Three Dimensions:** The unit helps students develop and use multiple grade-appropriate elements of the SEPs, CCCs, and DCIs which are deliberately selected to make sense of phenomena or design a solution to a problem.
- **Integrating the Three Dimensions for Instruction and Assessment:** The unit will elicit student artifacts that show direct, observable evidence of three dimensional learning.
- **Relevance and Authenticity:** By taking advantage of student questions and experiences in the context of their homes, neighborhood and community, the lessons in this unit will motivate student sense-making or problem-solving.
- **Student Ideas:** This unit provides opportunities for students to express clarify, justify, interpret or represent their ideas and to respond to peer and teacher feedback.
- **Building on Students' Prior Knowledge:** Since student understanding grows over time, this unit identifies and builds on students' prior learning in three dimensions in such a way as it is explicit to both students and teachers.

Assessment:

Providing opportunities for assessment of learning and feedback to students is an important step in the educational process. This unit includes embedded formative assessments. The teacher is encouraged to use a variety of informal or anecdotal assessment strategies as well, such as: portfolios of artifacts, "thumbs up" & "thumbs down", "ticket out the door", regular perusal of student science journals.

Additional Features of this Unit

The **Waves and Electromagnetic Radiation** unit also includes Science Journal pages that are available online at the BOCES 4 Science website. (A web address and password are located within the science kit.)

Additional resources for the teacher, such as the specific assessments, direct links to videos or websites mentioned in the teacher's guide, etc. can also be found on the BOCES 4 Science website under MS Waves.

Features that Support 3-D Learning

Look for these features in the Teacher's Guide:

NYS pK – 12 Science Learning Standards within each lesson provide the teacher with specific information about the Performance Expectation and the 3-Dimensions that are targeted by the instruction in this lesson.

Performance Expectations:
K-2-ETS1-2 – Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

Science and Engineering Practices

Asking questions & defining problems

Asking questions and defining problems in grades PK – 2 builds on prior experiences and progresses to simple descriptive questions that can be tested.

- Asking questions based on observations such as cause & effect relationships.

Disciplinary Core Ideas

ESS2-D: Weather and Climate

- Scientists record patterns of the weather across different times and areas so they can make predictions about what kind of weather might happen next.

Crosscutting Concepts

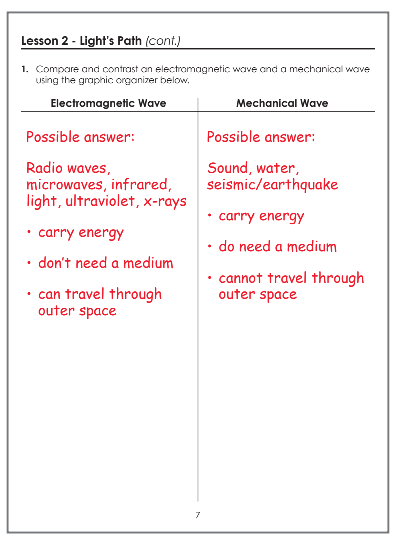
Patterns

- Patterns of change can be used to make predictions.

ELA/Math/Social Studies Connections:
ELA:
Math:
Social Studies:

Throughout the Teacher's Guide, the 3-Dimensional Domains are color coded within the text so that teachers know to emphasize or explicitly point out to students this connection to either the **Science and Engineering Practices (SEPs)** and the **Crosscutting Concepts (CCCs)**. In addition, small boxes on the sides of the Procedure pages (see box in the yellow column to the right) serve as a visual reminder, as well.

In addition, a small picture of the page(s) of the Student Science Journal (with answers) that students are using for each lesson has been included on the appropriate pages in the Teacher's Guide (see box to the right). This keeps the teacher from needing to go back and forth between various documents pertaining to a particular lesson.


Lesson 2 - Light's Path *(cont.)*

1. Compare and contrast an electromagnetic wave and a mechanical wave using the graphic organizer below.

Electromagnetic Wave	Mechanical Wave
Possible answer:	Possible answer:
Radio waves, microwaves, infrared, light, ultraviolet, x-rays	Sound, water, seismic/earthquake
• carry energy	• carry energy
• don't need a medium	• do need a medium
• can travel through outer space	• cannot travel through outer space

7

CCC: Crosscutting Concept(s):

Cause and Effect:
Events have causes that generate observable patterns.

New York State P-12 Science Learning Standards

M.S. Waves and Electromagnetic Radiation Standards

Performance Expectations: Students who demonstrate understanding can:

MS-PS4-1 – Develop a model and use mathematical representations to describe waves that includes frequency, wavelength, and how the amplitude of a wave is related to the energy in a wave. [Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [Assessment Boundary: Assessment is limited to comparing standard repeating waves of only one type (transverse or longitudinal).]

MS-PS4-2 – Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, ray diagrams, simulations, and written descriptions. Materials could include plane, convex, and concave mirrors and biconvex and biconcave lenses.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]

MS-PS4-3 – Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. [Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.] [Assessment Boundary: Assessment does not include binary counting. Assessment does not include the specific mechanism of any given device.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education:*

Science and Engineering Practices

Develop and use a model to describe phenomena (MS-PS4-2)

Use mathematical representations to describe and/or support scientific conclusions and design solutions (MS-PS4-1)

Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings (MS-PS4-3)

Connections to Nature of Science:

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS4-1)

Disciplinary Core Ideas

PS4.A: Wave Properties

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1)
- A sound wave needs a medium through which it is transmitted. (MS-PS4-2)

PS4.B: Electromagnetic Radiation

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2)
- (NYSED) The path that light travels can be traced as straight lines, except when it hits a surface between different transparent materials (e.g., air and water, air and glass) obliquely where the light path bends. (MS-PS4-2)
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. (MS-PS4-2)
- (NYSED) However, because light can travel through space, it cannot be a

Crosscutting Concepts

Patterns

- Graphs and charts can be used to identify patterns in data. (MS-PS4-1)

Structure and Function

- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS4-2)
- Structures can be designed to serve particular functions. (MS-PS4-3)

Connections to Engineering, Technology, and Applications of Science:

Influence of Science, Engineering, and Technology on Society and the Natural World

- Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations. (MS-PS4-3)

New York State P-12 Science Learning Standards

continued from page 8

mechanical wave, like sound or water waves. (MS-PS4-2)

PS4.C: Information Technologies and Instrumentation

- Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. (MS-PS4-3)

Connections to Nature of Science: Science is a Human Endeavor

- Advances in technology influence the progress of science and science has influenced advances in technology. (MS-PS4-3)

Connections to other DCIs in Middle School: **MS-PS3-5, MS-PS3-6**,

Articulation of DCIs across grade levels: **1 PS4-1,1-PS4-3, 1-PS4-4, 4-PS3-2, 4-PS4-1, 4-PS4-3, 4-PS4-2**

Common Core State Standards Connections

ELA/Literacy-

6SL1 Engage effectively in a range of collaborative discussions with diverse partners; express ideas clearly and persuasively, and build on those of others.

6SL2 Interpret information presented in diverse formats (e.g., including visual, quantitative, and oral) and explain how it relates to a topic, text, or issue under study.

6-8RST 1 Cite specific evidence to support analysis of scientific and technical texts, charts, graphs, diagrams etc. Understand and follow a detailed set of directions.

6-8 RST 2 Determine the central ideas or conclusions of a source; provide an accurate, objective, summary of the source distinct from prior knowledge or opinions.

6-8 RST 7 Identify and match scientific or technical information presented as text with a version of that information presented visually (e.g., in a flowchart, diagram, model, graph, or table).

6-8 RST 9 Compare and contrast the information gained from two or more experiments, simulations, videos, multimedia sources, readings from texts, graphs, charts, etc. on the same topic.

6-8 WHST 1 Write arguments focused on discipline-specific content.

6-8 WHST 2 Write informative/explanatory text focused on discipline-specific content.

6-8 WHST 3 Write narratives to understand an event or topic, appropriate to discipline-specific norms, conventions, and tasks.

Mathematics-

5 NBT. A-1 Recognize that in a multi-digit number, a digit in one place represents 10 times as much as it represents in the place to its right and 1/10 of what it represents to its left.

5 NBT. A.2 Use whole number exponents to denote powers of 10. Explain patterns in the number of zeros of the product when multiplying a number by powers of 10, and explain patterns in the placement of the decimal point when a decimal is multiplied or divided by a power of 10.

5NBT.A.3 Read, write, and compare decimals to thousandths.

5 NBT.A.3a Read and write decimals to thousandths using base-ten numerals, number names, and expanded form.

6 RP.A.1 Understand the concept of ratio and use ratio language to describe a ratio relationship between two quantities.

6EE.A.1 Write and evaluate numerical expressions involving whole-number exponents.

6.EE.A.2 Write, read and evaluate expressions in which letters stand for numbers.

Lesson 6

Lenses

Vocabulary:
concave
convex
focal point
lens
optics

Safety:
Students should be careful not to drop the lenses. Also, not to shine the light directly in the eyes of anyone.

Focus Question:
How do lenses bend light?

Lesson Synopsis

Learning Target:
I can make sketches of how different shapes of lenses will bend light.

Lesson Description:
The students will investigate how the shape of different lenses causes light to respond differently when it passes through them.

Management

Materials

For each pair of students:

3 lenses from Light Blox kit - biconcave, biconvex, and trapezoid
3 Light Bloxs from the kit (with line cap)
Magnifier
8 ½ "x 14" white paper*

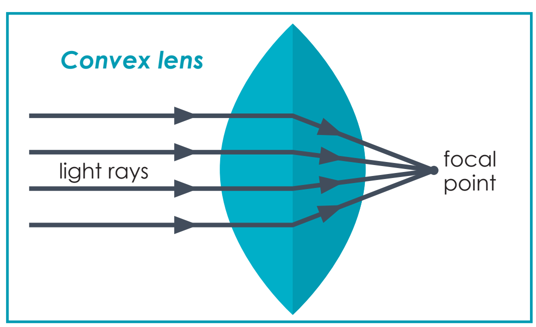
For each student:

Student Science Journal pages 19-20

*provided by teacher/student

Preparation:
This activity works best in a darkened room.

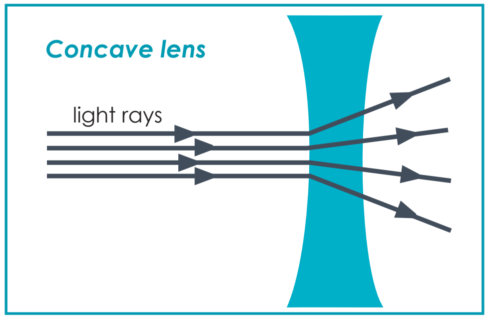
Teacher Background:
One way we can manipulate light to make it do what we want to do is by using lenses to change the direction of light. A **lens** is a piece of transparent glass or plastic that is shaped to refract light waves. The development and use of lenses is a major area of study within the field of **Optics**.



A **convex** lens is thicker in the middle than at the ends and causes light to bend towards the axis that goes through the center of the lens. In other words, it brings light waves closer together and can make an object appear larger or closer than it really is. In this lesson, as the three rays of light pass into and through the convex lens, the light rays all converge to a point. That point is called the **focal point**. The focusing ability of convex lenses helps us to see images clearly (i.e. lenses in glasses, contact lenses, hand lenses, microscopes, telescopes, cameras).

Lesson 6 Lenses *cont.*

A **concave** lens is thinner in the middle than at the ends and causes light to bend away from the axis that goes through the center of the lens. As the three light rays pass through the concave lens, you can see that they diverge or spread out. These lenses make objects appear smaller or farther away than they actually are (i.e. some eyeglasses and door peepholes).



Standards

Performance Expectations:

MS-PS4-2 – Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, ray diagrams, simulations, and written descriptions. Materials could include plane, convex, and concave mirrors and biconvex and biconcave lenses.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]

Science and Engineering Practices

Developing and Using Models

- Develop and use a model to describe phenomena.

Disciplinary Core Ideas

PS4.B: Electromagnetic Radiation

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2) (NYSED)
- The path that light travels can be traced as straight lines, except when it hits a surface between different transparent materials (e.g., air and water, air and glass) obliquely where the light path bends. (MS-PS4-2)
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. (MS-PS4-2) (NYSED)

Crosscutting Concepts

Patterns

- Graphs, charts, and images can be used to identify patterns in data. (MS-PS4-1)

Structure and Function

- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS4-2)

ELA/Math/Social Studies Connections:
ELA: 6SL1, RST 9

SEP: Science and Engineering Practice(s):

Develop and Use a model to describe phenomena

CCC: Crosscutting Concept(s):

Patterns

Graphs, charts, and images can be used to identify patterns in data. (MS-PS4-1)

Structure and Function

Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS4-2)

Vocabulary:
- **concave** - a lens that is thinner in the middle than at the ends
- **convex** - a lens that is thicker in the middle than at the ends
- **focal point** - point where light rays meet when light is refracted by a lens
- **lens** - a piece of transparent glass or plastic that is shaped to refract light waves
- **optics** - the study and technology of using light when it behaves like a wave

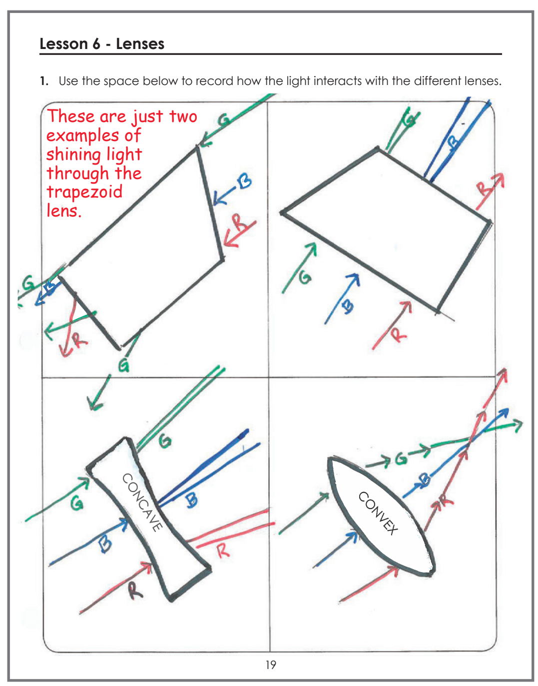
Procedure

Phenomenon:

Light bends (refracts) in different ways when it passes through different shaped lenses.

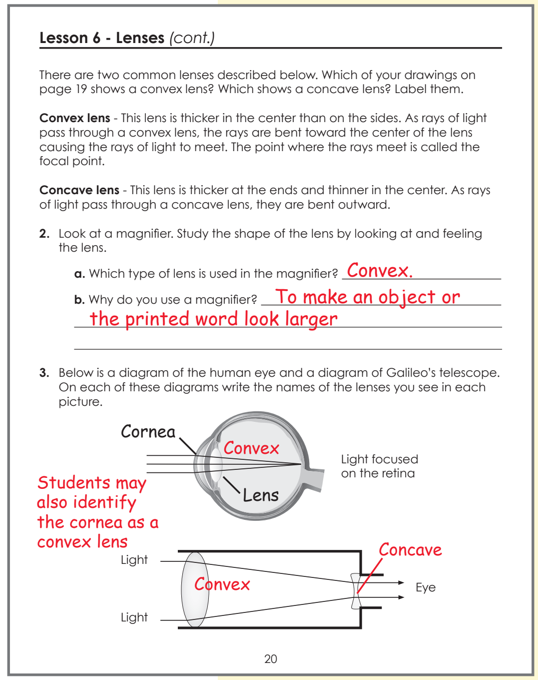
Procedure:

1. Have students shine each of the Light Blox through the trapezoid lens in a variety of ways using all three lights. Students can move the lens and/or move the light and make observations about how the light rays respond after being transmitted through the lens.
2. Ask students to **draw a model** of the ways they positioned the lights and the lens, including sketching in the way the light responded. Use page19 in the Student Science Journal to document results. Students should discuss their observations with their partner.
3. Lead a discussion about how the light responded to the lens. Did students notice any **patterns** in their observations? Students should use their **models** to explain the results.
4. Show students the two other lenses in their Light Blox kit. Discuss how these lenses are structurally similar to and different from each other (**structure and function**).
5. Ask students to take these other two lens. Student should shine beams of light from all three light bloxs at each of these two lens. In their Student Science Journal on page 19 students should draw an outline of the shape of each lens and the path the beams of light take after passing through the lens.
6. Pass out magnifiers. Have students figure out, through seeing and feeling, what type of lens this is. Why do we use magnifiers?



Closing the Lesson

Lead a discussion about how the light responded to each of the lenses. In their Science Journals are diagrams of the eye and Galileo's telescope. Ask students identify which type of lens they are seeing in each diagram. Have students come up with ideas as to why this type of lens is being used.



Lesson 6 - Lenses *(cont.)*

There are two common lenses described below. Which of your drawings on page 19 shows a convex lens? Which shows a concave lens? Label them.

Convex lens - This lens is thicker in the center than on the sides. As rays of light pass through a convex lens, the rays are bent toward the center of the lens causing the rays of light to meet. The point where the rays meet is called the focal point.

Concave lens - This lens is thicker at the ends and thinner in the center. As rays of light pass through a concave lens, they are bent outward.

2. Look at a magnifier. Study the shape of the lens by looking at and feeling the lens.

a. Which type of lens is used in the magnifier? Convex.

b. Why do you use a magnifier? To make an object or the printed word look larger

3. Below is a diagram of the human eye and a diagram of Galileo's telescope. On each of these diagrams write the names of the lenses you see in each picture.

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Assessment

Through whole group discussion and conversations with students as they work in pairs, assess their understanding. By the end of the lesson, students should understand that the structure of the lens can function to enlarge the image of an object or make the image smaller.

Connections

Differentiation:

Talk with the librarian for additional resources on lenses for students who wish to pursue this topic further. Students with an interest in Astronomy may be interested in the learning more about telescopes.

Cross-Discipline:

Check to see if the Optical Society of America is affiliated with one of the local Universities or colleges. The Optical Society offers the Optics Suitcase to Middle Schools. The suitcase has several activities that build off this lesson and connect this learning to Optical Engineering. Optical Engineering is closely allied with Photonics.

Next Lesson Preparation

Find the flashlights, the laser pointer and the batteries. Students will be using the flashlights; the teacher will be using the laser pointer. Additional materials that are used in the next lesson are the red cellophane, black construction paper, rubber bands, tape measures, diffraction grating.

Comparing Light

Vocabulary:
dependent variable
fair test
independent variable
laser
monochromatic
photonics

Focus Question:
How does the light from a laser pointer compare to the light from a flashlight?

Lesson Synopsis

Learning Target(s):

I can plan and carry out an investigation comparing the light from a laser pointer to the light from a flashlight.

I can identify some of the unique properties of laser light.

Lesson Description:

This lesson was developed when the unit's focus was **Photonics**. The purpose of this lesson is to introduce students to the **laser**. Lasers were key in the development of the Photonics industry. This lesson provides a good opportunity for students to review **planning and carrying out investigations**. Students work in teams to plan and carry out an investigation comparing the light from a flashlight with light from a laser pointer. By the end of the lesson, students should realize some of the unique properties of lasers. In planning the investigation, students should be familiar with the idea of a **fair test** and the need to keep constant all variables except those which are being tested. The terms **independent** and **dependent** variables are one which Middle School students are expected to know by the end of 8th grade. These terms can be discussed in this lesson should you choose.

Lesson 7 was inspired by Lesson 1 from The Physics of LASERs published in 2010 by the American Physical Society.

Management

Safety:
The laser pointer is to be used only by the teacher.

Materials

For the whole class:

1 laser pointer under teacher's control

For student teams to use:

Black construction paper
Flashlight
Diffraction grating film and/or diffraction slides from Light Blox kit
Masking tape
Red cellophane
Rubber bands
Rulers
Sticky notes
Tape measures/rulers

For each student:

Student Science Journal pages 21-23

*provided by teacher/student

Lesson 7 Comparing Light *cont.*

Preparation:
Be prepared to dim the lights in the room. Desks and posters on the wall may need to be re-arranged so that students can shine flashlights on the wall.

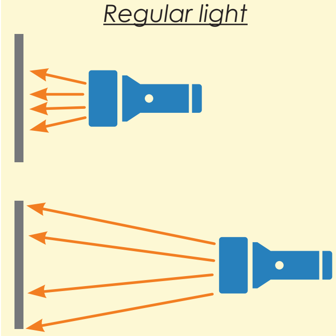
Rulers and tape measures have been provided in the kit should students choose to measure the width of a beam of light from a flashlight. If yard or meter sticks are available, these may be more helpful than the tape measures for measuring broad beams of light.

"If a student stares deliberately into a laser beam, permanent and irreparable eye damage can occur. The National Science Teachers Association recommends that students below high school level not handle the laser pointer instead the teacher should perform demonstrations. To reduce the chance of eye damage do not completely darken the room when doing demonstrations." (p.8 The Physics of LASERs published in 2010 by the American Physical Society.)

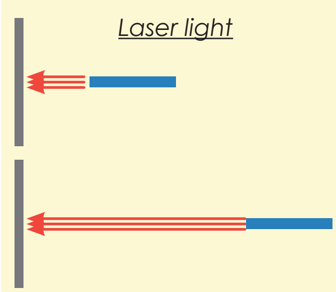
Teacher Background:
Photonics is the study and technology of using light when it behaves as a particle of energy. This unit started with a video titled "A Day without Photonics- A Modern Horror Story". In this lesson, we return to the subject of Photonics as students observe some of the unique properties of the light from a laser. The laser was an early development in the field of photonics. Light from a laser can travel in a straight line over long distances without loss of intensity or sharpness of focus. Lasers can be made to emit light beams of such power that the beams can cut metal. The intense energy and the pinpoint focus of a laser beam have resulted in the laser being incorporated into a number of inventions over the past 50 years that range from LASIK eye surgery to bar code readers. Today lasers are an integral part of such devices as CD and DVD players, printers, tools for measuring distance, and fiber optics- just to name a few.

There are three unique properties to a beam of light from a laser. The light is **monochromatic**, collimated and coherent. These are not words that students need to be held accountable for knowing. At the end of this activity students should observe the first two properties. The light from a laser is monochromatic which means one color. With the pointer used in this activity that color is red. The use of the diffraction grating film indicates the purity of this color. The other property students will observe is collimated. The word directional is often substituted for the word collimated. Collimated means every ray of laser light travels in the same direction parallel to the other rays. That is not true with the light from a flashlight. Each ray of light from the flashlight travels in a straight line (this was made clear in Lesson 2) but the rays do not travel parallel to each other. The farther from the wall a person stands holding a flashlight, the greater the scattering of light rays as the rays travel toward the wall. This is why the light on a wall becomes blurrier as one moves farther back from the wall. If one continued to move back from the wall there would be a distance at which the light would be so scattered that it would no longer be noticeably on the wall. This is not the case with a beam from a laser. At great distances from the wall, the beam of laser light will still precisely hit a target on the wall.

Regular light



Laser light



Standards

Performance Expectations:

MS-PS4-2 – Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, ray diagrams, simulations, and written descriptions. Materials could include plane, convex, and concave mirrors and biconvex and biconcave lenses.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]

Science and Engineering Practices

Planning and Carrying Out Investigations

- Plan an investigation Individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

Disciplinary Core Ideas

PS4.B: Electromagnetic Radiation

- The path that light travels can be traced as straight lines except when it hits a surface between different transparent materials (e.g. air and water, air and glass) Obliquely where the light path bends.

Crosscutting Concepts

Patterns

- Graphs, charts, and images can be used to identify patterns in data.

Structure and Function

- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

Connection to Nature of Science

- Science is a human endeavor. Advances in technology influence the progress of science and science has influenced advances in technology.

ELA/Math/Social Studies Connections:
ELA: 6SL1, 6-8 RST 9, 6-8 WHST 2, 6-8 WHST 3

Vocabulary:

- **dependent variable** - the variable that is observed and/or measured during an investigation
- **fair test** - a test where only one factor is changed at a time while all other factors are kept constant
- **independent variable** - the variable that is intentionally changed in an investigation to see what effect this has on the dependent variable
- **laser** - a concentrated beam of light comprised of one color
- **monochromatic** - one color
- **photonics** - the study and technology of using light when light behaves like a particle of energy

Misconceptions: Students may not realize the dangerous nature of a laser, and that a laser can cause permanent blindness.

Procedure

Phenomenon:

The phenomena, that drive this lesson, are the unique characteristics of a laser such as the laser's ability to maintain focus and intensity over a distance.

The teacher will demonstrate these characteristics at the beginning of this lesson by using a laser pointer. All students need to be out of the path of light from the laser. Described here is one way for a teacher to demonstrate the characteristics of a laser. The teacher should place a sticky note on the wall. Stand fairly close to the wall and shine the laser pointer on the wall so the beam of light hits the center of the sticky note. The teacher should walk backward, continuing to direct the laser beam at the sticky note on the wall. The teacher should walk as far back from the wall as is possible given the layout of the room.

When done with this demonstration, the teacher should ask students what they noticed about the light from the laser. Answers might include the red color, the beam of light stayed focused on the sticky note. The diameter of the beam of laser light on the sticky was narrow and remained approximately the same size regardless of how far back from the wall the teacher stood.

Walk around showing the laser pointer to students so they can observe its structure. Consider taking out the batteries so students can handle the laser. What are some things that students notice about the laser? Looking at the pointer, students may notice that the pointer is narrow and there is only a small opening out of which light is emitted.

Activity #1 Procedure

1. Ask students what a **fair test** is? (A test in which we keep all the variables the same except for the variable(s) which we are testing.) If students were to design a fair test to compare light from a "regular" flashlight to the light from a laser, how would they go about doing that?
2. Organize students into teams of three. Show teams the materials that are available for use. (Materials include flashlight, tape measure, sticky notes, red cellophane and black construction paper.)
3. Ask students to think about the demonstration that they just saw and to come up with a plan to compare light from the flashlight with the light from a laser (page 21 in the Student Science Journal). In developing this investigation students are not allowed to use the laser pointer but they may ask you, the teacher, to use it for them as part of their investigation.
   a. In planning this investigation, teams need to think about what observations they should record. What should their data table look like?

SEP: Science and Engineering Practice(s):

Planning and Carrying Out Investigations

Plan an investigation Individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

Lesson 7 - Comparing Light

Question: How does the light from a regular flashlight compare to the light from a laser pointer?

Materials available for your use:
Black construction paper, Ruler
Flashlight, Tape
Sticky pad, Tape measure
Red cellophane
Anything else you need?

Safety Precautions: Do not shine flashlights directly into other students' eyes.
Do not stare into the light from the laser pointer.
Teams cannot use the laser pointer.

Things to consider: What is the purpose of your investigation?
What are your variables?
Which variables need to be kept constant?
What data are you collecting?

Your Procedure: Sample procedure from one of the ways that this investigation could be done.

1. Place a sticky note on the wall
2. Measure and mark a distance 30 cm from the wall, 60 cm, 100 cm, 200 cm, 300 cm, 400 cm and 500 cm.
3. Stand at each distance from the wall and shine the flashlight onto the sticky note.
4. Rate the width of the light beam as it falls on the sticky note. 1=clear beam width about same as the flashlight or pointer. 10=blurry broad beam
5. Repeat with teacher using the pointer.

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Lesson 7 Comparing Light *cont.*

4. Have each team **develop an investigation** and show it to you for your approval. Once they have your approval they may run the investigation.
    a. Typically teams develop a plan that is similar to the teacher's demonstration. They set a sticky note on the wall. Then at set distances, shine the flashlight at the sticky and measure the diameter of the beam of light hitting the wall. A broader beam of light indicates a less intensely focused beam of light. Instead of measuring, students may come up with a scale to describe the "sharpness" of the light beam as it hits a surface like the wall. An example of such a scale might be a rating from 0 to 5 with 0 being very blurry and 5 being very clear.
    b. Teams might believe that to run a fair test the light from the flashlight should be red and/or that the light from the flashlight should go through a narrow opening like that on the laser. These teams can rubber band a sheet of red construction paper and/or black construction paper around a flashlight. Note the black construction paper has a small hole punched in it.
    c. If students want to collect similar data on the laser pointer, you, the teacher, should handle the laser. For reasons of safety, the diameter of the light beam from the laser should not actually be measured but instead be estimated.

CCC: Crosscutting Concept(s):

Patterns

Graphs and charts can be used to identify patterns in data.

5. When students have completed making and recording their observations. Have a whole class discussion about the findings. What trends/**patterns** are there in the data. (Light from a flashlight loses its intensity and becomes blurrier at greater distances from a target.)
    a. Review or introduce the words **independent** and **dependent variable**. What was their independent variable? (In the experiment described here, the independent variable was the different distances from the wall.) What was the dependent variable? (In the experiment described here, the dependent variable was the diameter of light hitting the wall or a rating for blurriness.)

Lesson 7 - Comparing Light *(cont.)*

Investigation Results:

There are different ways to run this investigation and set up the data collection table. This is just one approach.

Distance (cm) from Wall	Flashlight	Laser Pointer
30	1 (5)	1
60	4 (5.5)	1
100	6 (6.0)	1.5
200	8 (9.0)	1.8
300	9 (12.0)	2
400	9 (15.0)	2
500	10 (17.0-18.0)	2

In parentheses are the measured width (cm) of the light beam from the flashlight. Rating system - 1 to 10 where 1 = clear beam with width about the same as the flashlight or pointer and 10 = blurry, broad beam.

Comments: Hard to compare laser with flashlight using a rating system. While the laser beam increased slightly in size as we moved further from the wall, it did not increase as quickly in size as the flashlight and the laser did not get blurry.

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Activity #2 Demonstration with Diffraction Grating

6. Pass out a sheet of diffraction grating and/or a diffraction slide from the Light Box Kit to each team plus a flashlight. Have students shine light from the flashlight onto the diffraction grating as they are looking at light from the flashlight. Have students hold the grating up and look though it at the ceiling lights or other sources of light in the room (except laser sources). What do they see? (a rainbow effect of colors.) Why? (The diffraction grating breaks light down into its component colors of red, orange, yellow, green, blue and violet.)
7. Situate the students so they are out of the path of the laser, and shine the laser through the diffraction grating at the wall. What do students see? (probably dots of red) Why isn't there the rainbow effect like students saw with the flashlight or ceiling lights? Is there something special about the laser's color? (The light from the laser is purely one color.) Prove this by covering the flashlight with red cellophane and looking through the diffraction grating at the red tinted light. (There is still a rainbow effect but perhaps not as many colors.)
8. Review with students the unique features that they have observed about lasers. Lasers give off a light that is pure in color. Lasers maintain a narrow intense beam of light over a distance. On page 23 of the Student Science Journal, have students write a conclusion to their investigation. In the conclusion, students should contrast laser light with light from a regular flashlight.

Lesson 7 - Comparing Light *(cont.)*

Conclusion: In the conclusion, contrast the characteristics of the light from a laser with the light from a flashlight.

The light from the laser was brighter and more intense than the light from the flashlight. The light from the laser kept a sharp focus directly on the sticky note even at 500 cm. The light from the flashlight did not.

When we used the diffraction grating, the light from the laser was just one color of red. The light from the flashlight was not just one color but was broken down into several different colors.

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Closing the lesson

Tell students that there are three special features of the light produced by a laser. The light is monochromatic, collimated and coherent. Students have already witnessed the first two features. Monochromatic means one (mono) color (chroma). Students witnessed that with diffraction grating. Collimated mean all rays of light travel parallel to each other in one direction. Students witnessed the opposite of that when they did their investigation with the light from a flashlight. With the flashlight, the rays of light went off in all directions. In future lessons, students will look at the structure of the laser to understand how it functions to produce light with these three features.

Safety:

Only the teacher should handle the laser pointer. Shine the light from the laser through the grating at the wall. Students can shine a flashlight towards them while looking through the diffraction grating at the light. **This should never be done with the laser pointer.**

CCC: Crosscutting Concept(s):

Structure and Function

Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.