Introduction to Optics

Grade/ Grade Band: Middle / High School	**Topic:** Physical Science, Physics

Brief Lesson Description: Students explore the science of optics through hands-on activities.

Performance Expectation(s):

MS-PS4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
HS-PS4-1: Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
HS-PS4-5: Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

Specific Learning Outcomes:

1. Students will understand the principles of optics related to night vision technology.
2. Students will engage in hands-on activities to demonstrate the principles of light and optics.
3. Students will explore the functions and applications of night vision goggles.
4. Students will develop collaboration and decision-making skills.

Optional PocketLab Activity Learning Outcomes:

1. Students will learn the difference between polarized and unpolarized light.
2. Students will create a model for investigating polarized and unpolarized light.
3. Students will use a polarizing filter and a light sensor to collect data on polarized versus unpolarized light.
4. Students will plan an investigation to determine whether sunlight is polarized or not.

Narrative / Background Information

Prior Student Knowledge:

- As this is an introductory lesson, there are no science or light and optics-specific prior knowledge requirements.
- In general, students should have experience using lab equipment, drawing what they see, and asking and discussing questions.

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
Developing and Using Models Develop a model to describe phenomena. (MS-PS4-2) **Obtain, Evaluate and Communicate Information** Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically) (HS-PS4-5) **Using Mathematics and Computational Thinking** Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-PS4-1)	**PS4.A: Wave Properties** A sound wave needs a medium through which it is transmitted. (MS-PS4-2) The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (HS-PS4-1) Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-5) **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) The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) 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) However, because light can travel through	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS4-1) Systems can be designed to cause a desired effect. (HS-PS4-5) **Structure and Function** Structures can be designed to serve particular functions by taking into account the properties of different materials, and how materials can be shaped and used. (MS-PS4-2) **Connections to Engineering, Technology and Applications of Science** **Influence of Science, Engineering, and Technology on Society and the Natural World** Modern civilization depends on major technological systems. (HS-PS4-5) **Interdependence of Science, Engineering and Technology**

	space, it cannot be a matter wave, like sound or water waves. (MS-PS4-2) Photoelectric materials emit electrons when they absorb light of a high enough frequency. (HS-PS4-5) **PS4.C: Information Technologies and Instrumentation** Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (HS-PS4-5)	Science and engineering complement each other in the cycle known as research and development (R&D). (HS-PS4-5)

Possible Preconceptions/Misconceptions:

Misconception 1: Light always travels in straight lines.
Correction 1: Light travels in straight lines in a uniform medium but can bend when passing through different media (refraction).

Misconception 2: All lenses magnify objects.
Correction 2: Lenses can either magnify (convex) or reduce (concave) the size of an image.

Preconception 3: Mirrors always produce an exact replica of an object.
Correction 3: Mirrors can produce various types of images, including real, virtual, inverted, and magnified, depending on their shape and placement.

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:

Begin by having students watch the following video highlighting various phenomena related to optics and light. It is one minute long, you can keep it on repeat, much like an extended version of a GIF. Each individual clip is numbered. After watching the first time, have students construct a SEE / THINK / WONDER table in their notes. Alternatively, teachers may have students fill out a Phenomena Asking Questions Graphic Organizer. Helpful information and additional links can be found in the video's description. Continue the video on repeat while the students add to their table. When finished, have students pair share and add a few additional ideas from their partners' tables onto their own tables.

Students can write down some of their thoughts from SEE / THINK / WONDER on a collective class document (this can be a class whiteboard, post-its in a designated area, or in an online space). What other light and optics phenomena and examples can you think of?

Video Link: Light and Optics Phenomena

Teacher note: This Phenomena Asking Questions Guide is for teachers and provides more specific details.

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:

Teachers will determine if they want to complete Option 1 (Non-technology option) or Option 2 (Pocket Lab Voyager Option) for this portion of the lesson.

Option 1: Non-Technology Option

Students will explore light and optics in the science classroom. This section of the lesson is designed to be an introduction and to give students a fun and engaging opportunity to play around with (explore) different tools and equipment. In addition to the free-play aspect of the section, students are also to start drawing diagrams of their setups and outcomes. What equipment was used? What was observed about the nature of light and optics?

1. Start by assembling as many stations as possible with equipment from the materials list - lights, laser pointers, mirrors, lenses, prisms, protractors, etc.
2. Randomly assign students into groups of 3 or 4. Each group will work at a table complete with a full set of materials. NOTE: If materials are in short supply, stations can be set up with specific materials at each spot, and student teams can then rotate around to the different equipment.
3. Provide students with different types of lenses (convex and concave) and mirrors (plane, concave, convex) and prisms. Using the laser pointers and flashlights have them investigate how light behaves when it passes through or reflects off these objects.

4. Prompt students by asking them to do two things:
    a. Explore/free play with the gear.
    b. After a certain amount of time, have them record their observations and draw diagrams of the light paths.
5. Encourage students to start simple, and work their way up in terms of complexity.

A few examples might include:
Mirrors: Reflection Angles
a. Have students shine a flashlight at different angles onto a plane mirror placed on a flat surface.
b. Using a protractor, measure the angle of incidence and the angle of reflection.
c. **Discussion:** What do you notice about the angles involved?

Prisms: Light Dispersion
a. Shine a flashlight through a triangular prism onto white paper.
b. Observe how the light splits into different colors (spectrum).
c. **Discussion:** What causes the light to split into different colors? How is this principle used in optics?

Lenses: Focusing Light
a. Provide convex and concave lenses.
b. Shine a flashlight through each lens onto a piece of white paper.
c. Observe how the light beam changes (converges or diverges).
d. **Discussion:** How do convex and concave lenses affect the path of light differently? Where might these types of lenses be used?

Option 2: Option utilizing PocketLab Voyager 2 Sensor
POLARIZED LIGHT INVESTIGATION **[link has full lab write-up and procedure]**

Set-Up: This interactive, sensor-based activity requires a PocketLab Voyager.
Investigation Question: Is sunlight polarized? Do polarized sunglasses protect our eyes more than non-polarized ones?
The goal of this investigation is to investigate the nature of light waves by using polarized filters to test how light is transmitted.

Procedure:
Part 1: Using a Filter with Unpolarized Light
First, we will test unpolarized light from a lightbulb and see how the polarizing filter affects the graph of light intensity.

1. Connect your PocketLab below and measure light intensity data.
2. Place or hold the PocketLab in front of your light source.
3. Start recording light intensity data.
4. After at least 5 seconds, place one of the polarizing filters in front of the light source. You can place it directly on top of the PocketLab.
5. Slowly rotate the filter 90 degrees.
6. Stop recording and save your trial

Note: You may notice the intensity of your light source goes up and down, forming a wave. This is normal for some electric lightbulbs.

Part 2: Using a Filter with Polarized Light
Next, we will test what happens when we use a polarizing filter on already polarized light.
1. Connect your PocketLab below and measure light intensity data.
2. Place or hold the PocketLab in front of your light source with one filter on top of it.
3. Start recording light intensity data.
4. After at least 5 seconds, place the second polarizing filter in front of the light source so they are aligned.
5. Slowly rotate the filter 90 degrees so they are misaligned.
6. Stop recording and save your trial

Part 3: Plan an Investigation
Use your model to write out a procedure that tests if sunlight is polarized using a polarized light filter and your PocketLab. What are the dependent, independent, and control variables? How will you analyze the data? Add a Data Analysis card to help you show your analysis.

Part 4: Further Observations - Optional
1. Hold your filter in the sunlight and observe its shadow. Rotate the filter. What do you notice about the shadow as you rotate it?
2. Hold your filter up to the sky and pay attention to the shade of the sky. Rotate the filter. What do you notice about the shade and color of the sky?
3. What does this tell you about the nature of sunlight?

EXPLAIN:

1. Facilitate a discussion where students share their observations from the Explore section above.
2. Start by having each team connect with one other group.
3. Have newly combined groups discuss the following Lab / Activity Group Discussion Questions.
    a. Depending on time, have each group select 3-4 questions to discuss.
4. After group discussions, one member of each group will briefly share insights from their groups.
5. Introduce the concepts of reflection, refraction, and absorption. Explain how different lenses and mirrors work and how they are used in everyday life, as well as in advanced technologies like telescopes and night vision equipment.
6. Show the video: **Veritasium**: How Do Night Vision Goggles Work?

Discussion Questions:

1. What did you find most surprising about night vision technology?
2. How do night vision goggles enhance our ability to see in the dark?
3. Can you think of other technologies that rely on optics?
4. How might night vision technology be useful in everyday life?
5. What are some potential drawbacks or limitations of night vision goggles?

ELABORATE: Applications and Extensions:
Law of Reflection + Building a Periscope.

1. Have students complete the Law of Reflection Lab. *Video presentation of the lab: HERE.
2. Have students Build a Periscope. Lab and instructions are from NASA STEM.

EVALUATE:

Formative Monitoring (Questioning / Discussion):

1. Have students complete the questions from the Law of Reflection Lab.
2. Discuss as a group, and then discuss as a class.
3. Questions throughout the lesson can be used to check students' understanding throughout the lesson. You can also assess student understanding through participation in discussions and activities, drawings, and analysis.

Summative Assessment (Quiz / Project / Report):
Give students this ten-question multiple-choice quiz on Night Vision and Optics**.** *Can be taken individually or as teams.

Additionally, teachers may assign these discussion questions:

1. Discuss how the principles they are exploring with mirrors, prisms, and lenses relate to the technology used in night vision goggles.
2. Highlight the importance of night vision technology in military operations for navigation, surveillance, and search and rescue missions, emphasizing the use of optics in enhancing these capabilities.
3. List other connections and applications for light and optics in the defense industry and in various technologies.

Elaborate Further / Reflect: Enrichment:

Choose one or more of the following activities to do as a class.
1. Build a Simple Telescope or Microscope: Have students construct their own simple telescope or microscope using lenses and cardboard tubes.
2. Create a Camera Obscura: Students can create a camera obscura, a simple optical device that demonstrates the basic principles of image formation.
3. Explore Polarized Light: Use polarized filters to explore how light waves can be filtered and the effects of polarization.
4. Investigate Refraction with Water and Glass: Perform experiments to observe refraction by placing objects in water and observing their apparent position changes.
5. Explore Additional Optics and Light Labs**.**

SOCIAL EMOTIONAL LEARNING ACTIVITY

Social Emotional Learning (SEL) Lesson: Responsible Decision-Making in Search and Rescue Operations
Case Study: In 2019, a group of hikers went missing in the dense forests of Washington State. The hikers had lost their way during a late afternoon hike, and by nightfall, they were unable to navigate back to the trailhead. The dense forest and lack of natural light made it impossible to see the trail markers. The local search and rescue team was called in to locate and rescue the hikers. Given the thick forest canopy and the darkness, the team relied heavily on night vision goggles to conduct their search. The night vision technology allowed them to see through the darkness and identify heat signatures from the hikers, ultimately leading to a successful rescue.

SEL Focus: Responsible Decision-Making

Discussion Questions: Have students discuss and share their responses to the following questions.

1. **Preparation and Strategy:**
   - How do you think the search and rescue team made responsible decisions when preparing for the rescue operation?
   - What factors did they consider to ensure they were well-prepared and safe during the search?
2. **Technology Use:**
   - How did the use of night vision goggles contribute to the success of the rescue mission?
   - What might have happened if the team had not used night vision technology?
3. **Communication and Collaboration:**
   - How might effective communication and collaboration among team members influence the outcome of the rescue operation?
4. **Alternative Solutions:**
   - If night vision goggles were unavailable, what alternative technologies or strategies could the team have used?
5. **Real-World Implications:**
   - How might the decision-making skills demonstrated by the search and rescue team be applied to everyday life situations?
6. **Reflecting on Personal Experience:**
   - Think about a time when you had to make a responsible decision in a challenging situation. What did you consider, and what was the outcome?

Conclusion

Summarize the key points about responsible decision-making in search and rescue operations. Emphasize the importance of considering multiple factors, collaborating effectively, and using technology responsibly to achieve successful outcomes.

INTERDISCIPLINARY CONNECTIONS/IDEAS

Math: Calculate the angles of incidence and refraction using Snell's Law.
History: Explore the history of optical discoveries, such as Galileo's telescope.
Art: Study how artists use light and shadow in their work, and how lenses are used in photography.

Materials Required for This Lesson/Activity

Quantity	Description
1 per group	laser pointer
> 1 of each kind per group	Mirrors - flat, concave, convex
> 1 of each kind per group	Lenses - various shapes and sizes, concave, convex
> 1 of each kind per group	Prisms - various shapes and sizes
1 per group	Flashlights
1 per group	2 flat mirrors , a cardboard tube with openings on each end, wooden supports ,tape
1 per group	protractors
1 per student	pencil/pen
1 per group	cups or beakers with water,lightbox, colored paper and cellophane

Lesson Created by David Madden
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