The Science of Directed Energy Technologies

Grade Band:Middle School and High School	**Topic:** Physical Science
Brief Lesson Description: Students explain how energy directed technologies use wave properties and their interactions of matter.	

Performance Expectation(s):

HS PS 4-4: Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.

HS ETS 1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

MS PS 4-1: Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.

MS PS 4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

Specific Learning Outcomes:

Students will….
-Understand the principles of directed energy technologies.
-Analyze the effects of electromagnetic radiation on different materials.
-Develop and evaluate solutions to real-world problems involving directed energy.
-Use mathematical models to describe wave properties.

Narrative / Background Information

To ensure students can successfully engage with the lesson content and activities, they should have the following background knowledge:

Middle School Standards:
-Familiarity with terms such as longitudinal wave, transverse wave, amplitude, wavelength, frequency, and speed of waves.
-Awareness of the electromagnetic spectrum, including visible light and other types of electromagnetic radiation (e.g., radio waves, microwaves, infrared, ultraviolet, X-rays, gamma rays).
-Understanding of how light can be reflected, absorbed, or transmitted through different materials
-Ability to use simple mathematical representations and calculations (e.g., measuring and recording data, basic graphing skills)..

High School Standards:
-In-depth understanding of wave properties, including the relationship between frequency, wavelength, and energy.
-Understanding of how different frequencies of electromagnetic radiation interact with matter.
-Skills in developing and evaluating solutions to real-world problems, considering criteria and constraints such as cost, safety, and environmental impact.
-Ability to create and interpret graphs, use rulers and calculators for measurements, and perform basic data analysis.

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
Developing and Using Models Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. ● Develop and use a model to describe phenomena. (MS-PS4-2) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs	**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 or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength	**Cause and Effect** ● Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-PS4-4) **Patterns** ● Graphs and charts can be used to identify patterns in data. (MS-PS4-1)

that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories.

- Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)

Obtaining, Evaluating and Communicating Information

Obtaining, evaluating and communicating information in 9-12 builds on K-8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. (HS-PS4-4)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.

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

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)

electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (HS-PS4-4,)

- 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 space, it cannot be a matter wave, like sound or water waves.(MS-PS4-2)

ETS1.B: Developing Possible Solutions

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)

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)

Connections to Engineering, Technology, and Applications of Science

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

- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Possible Preconceptions/Misconceptions:

Students come with a variety of preconceptions/misconceptions related to electromagnetic energy and light including:
-Believing that light always bounces back when it encounters a different medium, rather than sometimes bending (refraction)
-Assuming higher frequency electromagnetic waves travel faster than lower frequency waves. (In a vacuum, all electromagnetic waves travel at the same speed, the speed of light.)
-Thinking that transparent materials do not absorb any light, when in reality, they can absorb some light while transmitting most.
-Not understanding that different materials reflect light differently, affecting the intensity and angle of the reflected light.
-Believing that all forms of electromagnetic radiation are dangerous to humans, without understanding the variations in energy and their specific effects on matter.

Additionally, they may have preconception/misconception related to directed energy technologies including:
-Believing that directed energy technologies are purely fictional and not currently in use or development.
-assuming that lasers are only used for cutting materials, when they have multiple applications including communication, medical treatments, and defense.

-thinking that microwave radiation is only used in microwave ovens, not recognizing its applications in communication and radar technologies.
By proactively addressing these preconceptions and misconceptions, the lesson can help students build a more accurate and comprehensive understanding of waves, electromagnetic radiation, and directed energy technologies.

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:
Start the lesson by writing "Directed Energy Technologies" on the board. Ask students t***o use their background knowledge to predict what these technologies might be and how they might be used.*** Facilitate a brief class discussion on students' prior knowledge and initial thoughts.

Next, show this short video about directed energy technologies**.** After the video, ask students ***how they would change their prediction based on the information from the video.*** Next, ask students to generate 3 questions about this technology. Share as a class.

Explain to students that in this lesson they will be exploring the science of directed energy technologies and how they are applied in different applications.

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:
Provide each student with a copy of the Lab Handout. Start by reviewing the following safety precautions:

1. Do not point the laser pointer at anyone's eyes.
2. Handle all materials and equipment carefully.
3. Follow your teacher's directions at all times.
4. Remember to turn off the laser pointer when not in use to preserve battery life.

Next, review the Objective, Materials and Procedures with students and allow them time to complete the lab in groups.

After students complete the lab, discuss the following prompts:

1. ***Discuss how the different properties of materials (such as density, opacity, and surface texture) influenced the behavior of the laser light in terms of reflection, absorption, and transmission.***
2. ***Which material showed the most interesting behavior and why?***
3. ***How do these interactions help us understand the nature of light and the materials themselves?***
4. ***What materials might be ideal for constructing energy directed technologies? How could certain materials be used for protection against them?***

EXPLAIN:
Direct Instruction:

- Explain the concepts of electromagnetic radiation, wave properties (amplitude, wavelength, frequency), and how different materials interact with electromagnetic waves.
- Introduce the principles behind directed energy technologies and their real-world applications. This text provides key ideas to cover.
- Discuss the importance of evaluating the effects of different frequencies of electromagnetic radiation on various materials.

ELABORATE: Applications and Extensions:
Present a real-world problem where directed energy technology could be applied (e.g., using lasers for communication or defense) to each group of students.

Have students work in their groups to develop a potential solution to the problem, considering factors like cost, safety, reliability, and environmental impacts.

Each group should create a poster or presentation outlining their solution and the criteria they considered.

EVALUATE:

Formative Monitoring (Questioning / Discussion):
Prompts throughout the lesson in ***bold and italics*** and posters of graph two analysis can be used to check student understanding throughout the lesson. Student lab handouts and analysis questions can also be utilized.

Summative Assessment (Quiz / Project / Report):
Students can be assessed using the following short quiz:

1. ***Describe how the amplitude of a wave is related to its energy.***
2. ***Explain what happens when electromagnetic radiation is absorbed by matter.***
3. ***List two real-world applications of directed energy technologies and briefly describe how they work.***
4. ***Why is it important to evaluate the validity and reliability of claims made about new technologies?***

Elaborate Further / Reflect: Enrichment:
Design and Prototype a Directed Energy Device

- ***Objective****: Students apply their understanding of directed energy technologies to design and create a prototype device.*
- **Activities:**
    - Research and Planning: Students research various types of directed energy devices (e.g., laser pointers, microwave transmitters) and decide on a specific application for their prototype (e.g., a laser communication system, a solar-powered laser cutter).
    - Design: Using engineering principles, students design their device, creating detailed blueprints and specifying materials needed.
    - Prototype Development: Students build a scale model or working prototype of their device using available materials (e.g., low-power lasers, reflective surfaces, solar panels).
    - Presentation: Students present their designs and prototypes to the class, explaining the science behind their device, its potential applications, and any challenges they encountered during the development process.

CAREER CONNECTIONS

Directed Energy Technologies are just one of the exciting innovations in the field of Optics and Lasers. From the field of Photonics to the role of Optomechanical Engineer, there are many interesting careers for students to learn about. The following activity will provide students an opportunity to learn about these careers.

Go to https://usasciencefestival.org/resources/ to access the Student Career Resources.

Select the Optics & Lasers Industry from the Menu.

Have students browse the careers within your chosen cluster. Select one career that they would like to learn more about. They should then gather the following information using the student graphic organizer or in a class notebook:

- Job description and typical responsibilities
- Education and training required
- Skills and qualities needed
- Average salary
- Work environment and schedule
- Professional Organizations, Educational Programs, and Internship & ApprenticeOpportunities

Choose a Choice Board Activity and use the information gathered to complete the chosen activity.

Career Interview Write a set of 5-7 questions you would ask someone in this career. Include the responses based on your research.	**Pros and Cons Chart** Make a T-chart listing at least five pros and five cons of the career based on your findings.	**Career Poster** Design a poster or infographic showcasing key details about the career (e.g., job tasks, salary, skills, and job outlook).

Provide students an opportunity to share their findings with peers or with you.

SOCIAL EMOTIONAL LEARNING ACTIVITY

CASEL Domain Addressed: Self-Awareness and Responsible Decision-Making

Objectives:

- **Understand the importance of ethical considerations in technology design.**
- **Reflect on personal and societal values related to technology.**
- **Develop skills to evaluate ethical dilemmas in technology.**
- **Collaborate with peers to propose ethically sound technology solutions.**

Lesson Steps:

1. Introduction to Ethics in Technology
   - Begin with a brief discussion on what ethics means and why it is important in everyday decisions. Relate this to technology design by explaining how ethical considerations can impact society.
   - Discussion Questions:
     - "*What are ethics, and how do they guide our actions?"*
     - *"Why do you think ethics are important when designing new technologies?"*
     - *"Can you think of a technology where ethical considerations were important?"*

2. Scenario Analysis
   - Divide students into small groups and provide each group with a handout containing different ethical scenarios related to technology
   - For each scenario, groups should use sticky notes to identify 1-3 positive and negative impacts of each scenario.
   - Pick one scenario and discuss possible solutions and how they align with personal ethical principles.

3. Group Presentations and Reflection
   - Each group presents one scenario and their proposed solutions to the class.
   - Class Discussion:
     - *Reflect on how each group approached the ethical dilemma.*
     - *Discuss common themes and differences in ethical considerations.*
     - *Encourage students to think about how their own values influenced their solutions.*

4. Personal Reflection
   - **Have students individually reflect on the following questions and write their responses:**
     - **"***What personal values do you think are important when designing technology?"*
     - *"How can you ensure that your future technology designs consider ethical implications?"*
   - Sharing (Optional): Students can share their reflections in pairs or small groups.

5. Wrap-Up and Closing
   - Summary: Recap the key points discussed about the importance of ethics in technology design.
   - Final Thoughts: Emphasize the role of ethics in creating technologies that are beneficial and fair to all stakeholders.
   - Call to Action: Encourage students to apply ethical thinking in their future projects and decisions.

INTERDISCIPLINARY CONNECTIONS/IDEAS

History and Social Studies: The Evolution and Impact of Directed Energy Technologies
-Research and create a timeline of key developments in laser and microwave technology and use the information to debate the ethical implications and societal impacts of using directed energy technologies in warfare and civilian applications.

Language Arts: Science Fiction and Reality
-Students will read and analyze excerpts from science fiction literature or watch clips from sci-fi movies featuring directed energy technologies and then write an essay or create a multimedia presentation comparing fictional portrayals with actual technologies and their uses. Use this article as a starting point.

Mathematics: Modeling and Calculations in Directed Energy Applications
Students can analyze data from the hands-on activities (e.g., intensity of transmitted light through different materials) using statistical methods.

Art: Visualizing the Invisible
Develop an artistic project that depicts the use of directed energy technologies in various applications (e.g., medical lasers, communication systems). Then, host a gallery walk where students present and explain their artwork to the class.

Materials Required for This Lesson/Activity	
Quantity	**Description**
Science Lesson:	
1 per group	Laser Pointer
1 sample per group	Plastic, Glass, Metal, Water,
1 per group	Ruler and Protractor
1 per group	Light Sensor (Possible options include Pocket Lab Voyager or Light Lux Meter Pro App in Google/Apple App Stores)
SEL Activity:	
1 handout per group	Ethics and Technology Scenarios
1 pad per group	Post It Notes

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