

## Unit #15 Properties of Light

Nature of Light, Color & the Electromagnetic Spectrum, Polarization & Scattering of light.

**Big Idea:** Light is a small but important part of the electromagnetic spectrum. Everything you see, either emits or reflects light.

### Essential Questions:

- What are the properties of light?
- Can you solve for the frequency or wavelength given the other?
- Can you describe various uses for the different wavelengths/frequencies of the electromagnetic spectrum?
- How does the Doppler Effect apply to light?
- How does the speed of light depend on the speed of the observer?
- What are the differences between primary and complementary colors of light?
- How do the primary colors of light relate to the colors we see?
- How does pigment produce its characteristic color?
- What determines the direction of polarization and how is a beam of light effected by the polarizer?

### Vocabulary:

photon	electromagnetic wave	visible light	electromagnetic spectrum	primary colors
primary colors	subtractive primary colors	polarization	polarizer	additive

Students who demonstrate understanding can:

- HS-PS3-2**      **Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).**[Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]
- HS-PS4-1.**      **Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.**[Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [*Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.*]
- HS-PS4-2.**      **Evaluate questions about the advantages of using a digital transmission and storage of information.**[Clarification Statement: Examples

copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.]

**HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.**[Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] [*Assessment Boundary: Assessment does not include using quantum theory.*]

**HS-PS4-4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.**[Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.] [*Assessment Boundary: Assessment is limited to qualitative descriptions.*]

**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.\*** [Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.] [*Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.*]

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	Disciplinary Core Ideas	Crosscutting Concepts
<p><b>Developing and Using Models</b> Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.</p> <ul style="list-style-type: none"> <li>Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS3-2)</li> </ul> <p><b>Asking Questions and Defining Problems</b> Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.</p> <ul style="list-style-type: none"> <li>Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. (HS-PS4-2)</li> </ul>	<p><b>PS3.A: Definitions of Energy</b></p> <ul style="list-style-type: none"> <li>Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system’s total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS-PS3-2)</li> </ul> <p><b>PS3.D: Energy in Chemical Processes</b></p> <ul style="list-style-type: none"> <li>Solar cells are human-made devices that likewise capture the sun’s energy and produce electrical energy. (<i>secondary to HS-PS4-5</i>)</li> </ul> <p><b>PS4.A: Wave Properties</b></p> <ul style="list-style-type: none"> <li>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)</li> <li>Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored</li> </ul>	<p><b>Cause and Effect</b></p> <ul style="list-style-type: none"> <li>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS4-1)</li> <li>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)</li> <li>Systems can be designed to cause a desired effect. (HS-PS4-5)</li> </ul> <p><b>Systems and System Models</b></p> <ul style="list-style-type: none"> <li>Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-PS4-3)</li> </ul>

### Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-PS4-1)

### Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed worlds. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-PS4-3)

### 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)
- Communicate 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)

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### *Connections to Nature of Science*

#### Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that

reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-5)

- [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) (HS-PS4-3)

#### PS4.B: Electromagnetic Radiation

- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS-PS4-3)
- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (HS-PS4-4)
- 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)

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### *Connections to Engineering, Technology, and Applications of Science*

#### Interdependence of Science, Engineering, and Technology

- Science and engineering complement each other in the cycle known as research and development (R&D). (HS-PS4-5)

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

- Modern civilization depends on major technological systems. (HS-PS4-5)

<p>have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-PS4-3)</p>		
<p><i>Connections to other DCIs in this grade-band:</i></p> <p><b>HS.PS1.C</b> (HS-PS4-4); <b>HS.PS3.A</b> (HS-PS4-4),(HS-PS4-5); <b>HS.PS3.D</b> (HS-PS4-3),(HS-PS4-4); <b>HS.LS1.C</b> (HS-PS4-4); <b>HS.ESS1.A</b> (HS-PS4-3); <b>HS.ESS2.A</b> (HS-PS4-1); <b>HS.ESS2.D</b> (HS-PS4-3)</p>		
<p><i>Articulation of DCIs across grade-bands:</i></p> <p><b>MS.PS3.D</b> (HS-PS4-4); <b>MS.PS4.A</b> (HS-PS4-1),(HS-PS4-5); <b>MS.PS4.B</b> (HS-PS4-1),(HS-PS4-3),(HS-PS4-4),(HS-PS4-5); <b>MS.PS4.C</b> (HS-PS4-5); <b>MS.LS1.C</b> (HS-PS4-4); <b>MS.ESS2.D</b> (HS-PS4-4)</p>		
<p><i>Common Core State Standards Connections:</i></p> <p><i>ELA/Literacy -</i></p> <p><b>RST.9-10.8</b> Assess the extent to which the reasoning and evidence in a text support the author’s claim or a recommendation for solving a scientific or technical problem. (HS-PS4-3),(HS-PS4-4)</p> <p><b>RST.11-12.1</b> Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS4-3),(HS-PS4-4)</p> <p><b>RST.11-12.7</b> Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS4-1),(HS-PS4-4)</p> <p><b>RST.11-12.8</b> Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-PS4-3),(HS-PS4-4)</p> <p><b>WHST.9-12.2</b> Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS4-5)</p> <p><b>WHST.11-12.8</b> Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS4-4)</p> <p><i>Mathematics -</i></p> <p><b>MP.2</b> Reason abstractly and quantitatively. (HS-PS4-1),(HS-PS4-3)</p> <p><b>MP.4</b> Model with mathematics. (HS-PS4-1)</p> <p><b>HSA-SSE.A.1</b> Interpret expressions that represent a quantity in terms of its context. (HS-PS4-1),(HS-PS4-3)</p> <p><b>HSA-SSE.B.3</b> Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS4-1),(HS-PS4-3)</p> <p><b>HSA.CED.A.4</b> Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS4-1),(HS-PS4-3)</p>		

