HIGH SCHOOL PHYSICS: WAVES

Standards Bundle

Standards are listed within the bundle. Bundles are created with potential instructional use in mind, based upon the potential for related phenomena that can be used throughout a unit.

HS-PS4-1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. (SEP: 5; DCI: PS4.A; CCC: Cause/Effect) [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-PS4-3 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. (SEP: 7; DCI: PS4.A, PS4.B; CCC: Systems) [Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified considering 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 Engage in an evidence-based argument for the effects that different frequencies of electromagnetic radiation have when absorbed by matter. (SEP: 7; DCI: PS4.B; CCC: Cause/Effect) [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-ESS1-2 Construct an explanation of the Big Bang Theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe. (SEP: 6; DCI: PS4.B, ESS1.A; CCC: Energy/Matter, Technology) [Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).]

Content Overview

This section provides a generic overview of the content or disciplinary core ideas as an entry point to the standards.

The relationships between the wave properties of speed, frequency, and wavelength can be represented mathematically. When waves move through different media, their properties can be changed. Models of electromagnetic radiation can be shown as both particles and waves. Electromagnetic radiation when absorbed can be converted to thermal energy, cause damage to living cells, or even cause materials to release electrons, therefore being converted into electrical energy. Different types of materials can absorb, reflect, or transmit electromagnetic waves. It is important to determine the full impact of the

advantages and disadvantages of our current use of and exposure to electromagnetism. Our view of the universe and all its contents is based on our understanding of the electromagnetic evidence we have observed, collected, and interpreted. By understanding the properties of electromagnetic radiation, we can infer that these properties are consistent throughout the universe and can tell us about it.

Phenomena

Phenomena can be used at varying levels of instruction. One could be used to anchor an entire unit, while another might be more supplemental for anchoring just a unit. Please remember that phenomena should allow students to engage in the SEP and use the CCC/DCI to understand and explain the phenomenon.

- Pictures of the universe or galaxies can be observed by images taken with different electromagnetic filters.
- Listen to the recording that NASA sent into space with the Voyager satellite.
- Draw two arrows on a piece of paper. Place an empty water glass in front of it and pour water into the glass halfway. The lower arrow changes direction.
- Seismogram or seismograph showing earthquake waves with varying amplitudes and arrival times for wave types.
- Video of how an ear works, receiving sound waves to converting them to electrical signals.
- A TV or other remote can turn something on when shined on a smooth surface away from the TV.
- On a sunny day the interior temperature of a car with a white interior is different than a car with a black interior.
- UV-color-changing beads change color when exposed to a black light.
- When colored lasers are shined through the end of your finger, it is transparent to only red laser light.
- Total internal reflection can be observed with a laser and a wave tank.
- Shine a sensitive flash mat or quinine water to show the difference in energy between red, green, and purple laser light.

Storyline

This section aims to decode not only the DCI connections but also the SEP and CCC in a detailed account of how they possibly fit together in a progression for student learning, including both rationale and context for the bundle.

Wave properties can provide a unique connection to how matter can interact with energy. The speed at which waves travel is related to the wavelength and frequency of the wave. Mathematical representation can be used to support a claim that shows this relationship. The speed of a wave can also be affected by the type of wave and the material through which it travels. Investigations can be planned and carried out using a variety of media, such as air, water, or solids to model this relationship. Patterns appear when waves are subjected to different frequencies and cause and effect relationships can be used to explain how this concept shows up in the different media listed above.

While evaluating the technological systems that use wave technology, data concerning the possible effects of using wave energy can be used. Many claims have been made about the effects caused by the use and conversion of energy on biological and thermal systems. Other information exists that would cause the further exploitation of the energy in waves to power the diverse instruments that make our society what it is today. Information concerning these claims may

be obtained from multiple sources, scientific and technological texts, or media reports. The data can be verified when possible and used to evaluate the validity of these claims. Using this information, the causes, and effects of society's current and continued uses on the environment, life, and society can be communicated.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking ● Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. **Engaging in Argument from Evidence** ● Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. **Obtaining, Evaluating, and Communicating Information** ● Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. **Constructing Explanations and Designing Solutions** ● Construct an explanation based on valid and reliable evidence	**PS4.A: Wave Properties** ● 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. ● Waves can add or cancel one another as they cross, depending on their relative phase (i.e., the 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 since two different sounds can pass a location in different directions without getting mixed up.) **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. ● 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. **ESS1.A: The Universe and Its Stars** ● The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. ● The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.	**Cause and Effect** ● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. ● 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. **Systems and System Models** ● Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions— including energy, matter, and information flows— within and between

obtained from a variety of sources (including students' investigations, theories, simulations, and peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	• Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. **PS4.B: Electromagnetic Radiation** • Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow the identification of the presence of an element, even in microscopic quantities.	systems at different scales. **Energy and Matter** • Energy cannot be created or destroyed– only moved between one place and another place, between objects and/or fields, or between systems.

Formative Assessment

Formative assessment is crucial because all learners benefit from timely and focused feedback from others. It promotes self-reflection, self-explanation, and social learning. It can also make learning more relevant. Each of the questions below might be used throughout the formative assessment process. Specific prompts may focus on individual practices, core ideas, or crosscutting concepts, but, together, the components need to support inferences about students' three-dimensional science learning as described in a given bundle, standard, or lesson-level performance expectation.

SEP Planning and Carrying Out Investigations

- Perform an investigation to compare surface temperatures of various surfaces of different colors or textures.
- Observe M & Ms under different colors of light and predict actual candy color based on knowledge of color subtraction.

SEP Developing and Using Models

- Use long springs or a long string attached to a drill to make waves of different wavelengths and frequencies - make measurements and observations to calculate wave speed.
- Computer simulations of wave properties and wave interference allow opportunities to manipulate frequency, amplitude, wavelength, and boundary behavior, and observe constructive and destructive interference patterns.

CCC Scale, Proportion, and Quantity

- Use diffraction grating to find the wavelengths of different colors of light.
- Analyze data on wave speed through various media to determine the relationship between wave speed & medium density.

Energy and Matter

- What is red shift and where can the evidence for red shift be found?
- How can emission and absorption spectra be used to infer the matter present in stars and interstellar gases?

Performance Outcomes

These are statements of how students use knowledge and are similar to the standards in how they blend DCI, SEP, and CCC, but at a smaller grain size. These are potential outcomes for instruction as it plays out in lessons and activities in the classroom. It is important to also think of these as smaller outcomes that build toward the larger goal of mastering the standards.

- **Use mathematical expressions** to show *the effect that changing* the wavelength or frequency of a wave will have on the wave's speed.
- **Use algebraic functions** to show the *cause-and-effect* relationship between the type of wave, the medium it travels through, and the wave's speed.
- **Analyze data** from a **planned investigation** to determine that when light and longer wavelength electromagnetic radiation are absorbed by matter, they are converted to thermal energy.
- **Argue based on evidence** from investigations that there is a *pattern* in the transformation of electromagnetic radiation to thermal energy based on the wavelength of the radiation.
- **Evaluate the claim** that shorter wavelength electromagnetic radiation (i.e., UV and shorter) can ionize atoms and cause damage to living tissue.
- **Create a model** showing that photoelectric materials emit electrons when they absorb light of a high enough frequency.
- **Evaluate questions** about the *dependence of modern civilization on technological systems utilizing electromagnetic radiation*.
- **Identify and describe the evidence to construct the explanations** including the composition of stars, the hydrogen-helium ratio of stars and interstellar gases, the redshift of the majority of galaxies and the redshift vs. distance relationship, and the existence of cosmic background radiation.