Physics Unit 6

Wave Properties

Overview

Unit abstract

In this unit of study, students are able to apply understanding of how wave properties can be used to transfer information across long distances, store information, and investigate nature on many scales. The crosscutting concept of cause and effect is highlighted as an organizing concept for these disciplinary core ideas. In the PS3 performance expectations, students are expected to demonstrate proficiency in using mathematical thinking, and to use this practice to demonstrate understanding of the core idea.

Essential question

- How are waves used to transfer energy and send and store information?

Written Curriculum

Next Generation Science Standards

<table>
<tr><td colspan="3">HS. Waves and Electromagnetic Radiation</td></tr>
<tr><td colspan="3">Students who demonstrate understanding can:
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.]</td></tr>
<tr><td colspan="3">The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:</td></tr>
<tr><td>Science and Engineering Practices
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)</td><td>Disciplinary Core Ideas
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. (HS-PS4-1)</td><td>Crosscutting Concepts
Cause and Effect
▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS4-1)</td></tr>
<tr><td colspan="3">Connections to other DCIs in this grade-band: HS.ESS2.A (HS-PS4-1)</td></tr>
<tr><td colspan="3">Articulation to DCIs across grade-bands: MS.PS4.A (HS-PS4-1); MS.PS4.B (HS-PS4-1)</td></tr>
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Common Core State Standards Connections:	
ELA/Literacy –	
RST.11-12.7	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)*
Mathematics –	
MP.2	Reason abstractly and quantitatively. (HS-PS4-1)
MP.4	Model with mathematics. (HS-PS4-1)
HSA-SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-PS4-1)
HSA-SSE.B.3	Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. *(HS-PS4-1)*
HSA.CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *(HS-PS4-1)*

Clarifying the standards

Prior learning

The following disciplinary core ideas are prior learning for the concepts in this unit of study. By the end of Grade 8, students know that:

Physical science

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.
- A sound wave needs a medium through which it is transmitted.
- When light shines on an object, it is reflected from, absorbed by, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- 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.
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

Progression of current learning

Driving question 1
What are the relationships among the frequency, wavelength, and speed of waves travelling in various media?

Concepts

- 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.
- Empirical evidence is required to differentiate between cause and correlation and to make a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

Practices

- Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
- Use algebraic relationships to quantitatively describe relationships among the frequency, wavelength, and speed of waves traveling in various media.

Integration of content, practices, and crosscutting concepts

In this unit, students will learn to identify and describe the characteristics of waves, including crests, troughs, speed, frequency, and amplitude. Students should also be able to identify nodes and antinodes. Students will use mathematical representations to show relationships among frequency, wavelength, and speed of waves using $v = \lambda\nu$ or, equivalently, $v = \lambda f$ (note that ν and f are used interchangeably to represent the frequency of a wave). These relationships should be explored for waves traveling through various media such as electromagnetic radiation traveling in a vacuum or through glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.

Density of materials should be considered in examination of waves traveling through different media. In calculations, students should be able to rearrange formulas to highlight quantities of interest. This unit will focus on mechanical waves, and students should develop an understanding that mechanical waves require a physical medium. Light waves will be addressed in terms of making claims about relationships among frequency, wavelength, and speed through calculations, and making observations of properties such as reflection and refraction. This foundation will provide the basis for addressing electromagnetic radiation waves more completely in Unit 7. Students will also explore both wave and particle models of electromagnetic radiation in Unit 7.

Students should develop an understanding of period with respect to frequency. Frequency is a quantity of rate—how often something occurs. Period is a quantity of time—how long it takes for something to occur. Students should have opportunities to investigate period and frequency. Students should develop an understanding that wave speed changes only as a result of a change in the wave's medium. For example, the speed of sound in air at STP is about 343 m/s, but the speed will also change due to changes in temperature and pressure of air. Students might investigate why Mach numbers change depending on altitude. Students can also consider the speed of light through air (2.998×10^8 m/s) and the speed of light in water (2.256×10^8 m/s). As students make claims using evidence from calculations, they should describe cause-and-effect relationships between changes in wave speed and type of media through which the wave travels. Claims should be based on evaluation of multiple sources of information and data.

In the previous unit, students considered the importance of P-waves and S-waves in understanding the composition of Earth's interior. They could now explore the properties of those waves in more detail by looking for relationships between seismic wave behavior and the Earth's internal composition. Other examples may include citation vocalizations and submarine transmissions. Some classroom activities might include using two linked, coiled springs of different materials to observe how wave behavior changes as it propagates from one medium to the next; placing a rod in a cylinder with fluids of different densities to observe refraction; and using a laser, Plexiglas rectangle, and protractor to determine the index of refraction. Students might also perform a vibrating string exercise. This could also be done with pitch analysis of sound (e.g., musical notes), using a computer simulation or tuning forks so that students can determine relationships between frequency and pitch.

Students should be able to distinguish between longitudinal, transverse, and surface mechanical waves and their behavior in different media. For example, sound is a longitudinal wave, whereas seismic S-waves are transverse waves. In a longitudinal wave, the particles of the medium move back and forth in the direction of the wave. In transverse wave propagation, the particles of the medium move in a perpendicular direction to the wave. Students should also know that surface waves propagate along the interface between two media with different densities, like the surface of a lake and air. Because earthquakes can produce both transverse and longitudinal waves, students should explore the relationship between transverse waves, longitudinal waves, and the Earth's molten core.

Students frequently harbor misconceptions about waves regarding frequency, period, amplitude, changing media, and wave speed. They should be able to make predictions about the behavior of waves traveling in various media and to discuss energy transmission, reflection, refraction, transmission, absorption, diffraction, and resonance.

Integration of DCI from prior units within this grade level

Students can make connections to their understanding of energy from Unit 4. To examine wave energy transfer, students might conduct research and analyze data from the 2004 tsunami in the Indian Ocean. Students can examine waves in terms of energy transport, transformations, transfer, and conservation. Students can also build on their understanding of seismic waves from Unit 5, relating the behavior of seismic waves to the different composition of the layers of Earth's internal structure.

Integration of mathematics and English language arts/literacy

Mathematics

- Represent symbolically relationships among the frequency, wavelength, and speed of waves traveling in various media, and manipulate the representing symbols. Make sense of quantities and relationships among the frequency, wavelength, and speed of waves traveling in various media.
- Use a mathematical model to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. Identify important quantities representing the frequency, wavelength, and speed of waves traveling in various media and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Interpret expressions that represent the frequency, wavelength, and speed of waves traveling in various media in terms of their context.
- Choose and produce an equivalent form of an expression to reveal and explain properties of the frequency, wavelength, and speed of waves traveling in various media.
- Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations when representing the frequency, wavelength, and speed of waves traveling in various media.

English language arts/literacy

- Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

Connected learning

Connections to disciplinary core ideas in other high school courses are as follows:

- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
- Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, and a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior.

- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

Number of Instructional Days

Recommended number of instructional days: 28 (1 day = approximately 50 minutes)

Note—The recommended number of days is an estimate based on the information available at this time. Teachers are strongly encouraged to review the entire unit of study carefully and collaboratively to determine whether adjustments to this estimate need to be made.

Additional NGSS Resources

The following resources were consulted during the writing of this unit:

- NGSS Appendices L and M
- *A Framework for K–12 Science Education*
- *Common Core State Standards for Mathematics* and *Common Core State Standards for Literacy in History/Social Studies, Science, & Technical Subjects*