Unit 5 Wave Properties & Sound

Content Area: **Science**
Course(s):
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Topic Outline

Vibrations

- Vibrational Motion / Properties of Periodic Motion
- Pendulum Motion / Motion of a Mass on a Spring

The Nature of a Wave

- Waves and Wavelike Motion / What is a Wave? / Categories of Waves

Properties of a Wave

- The Anatomy of a Wave / Frequency and Period of a Wave
- Energy Transport and the Amplitude of a Wave
- The Speed of a Wave / The Wave Equation

Behavior of Waves

- Boundary Behavior / Reflection, Refraction, and Diffraction
- Interference of Waves / The Doppler Effect

Standing Waves

- Traveling Waves vs. Standing Waves / Formation of Standing Waves
- Nodes and Anti-nodes / Harmonics and Patterns / Mathematics of Standing Waves

The Nature of a Sound Wave

- Sound is a Mechanical Wave / Sound as a Longitudinal Wave / Sound is a Pressure Wave

Sound Properties and Their Perception

- Pitch and Frequency / Intensity and the Decibel Scale
- The Speed of Sound / The Human Ear

Behavior of Sound Waves

- Interference and Beats / The Doppler Effect and Shock Waves
- Boundary Behavior / Reflection, Refraction, and Diffraction

Resonance and Standing Waves

- Natural Frequency / Forced Vibration
- Standing Wave Patterns / Fundamental Frequency and Harmonics

Physics of Musical Instruments

- Resonance / Guitar Strings
- Open-End Air Columns / Closed-End Air Columns

Unit Summary

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

In this unit of study, students apply their 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. Students are expected to demonstrate proficiency in *using mathematical thinking*, and to use this practice to demonstrate understanding of the core idea.

updated from 11.19.15

Enduring Understandings

- Waves transfer energy without transferring matter.
- Mechanical waves require a medium to propagate, however, electromagnetic waves do not.
- A continuous wave is a regular repeating sequence of wave pulses.
- Interference occurs when two or more waves move through a medium at the same time.
- Sound is a pressure variation transmitted through matter as a longitudinal wave.
- Sound is produced by vibrating objects in matter.
- The velocity of a wave is a function of the wavelength and frequency.

Essential Questions

- How are waves used to send and store information?
- How do waves transfer energy?
- How do waves interact?
- How do waves impact our lives?

Student Learning Objectives (PE, SEP, DCI, CCC) & Aligned Standards

- Students will use equations to solve problems involving the speed of sound, wavelength, frequency, and period.

Performance Expectations

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-PS4-1)**

Science and Engineering Practices

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)

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)

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)

SCI.9-12.1.3	Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system.
SCI.9-12.1.4	Mathematical representations are needed to identify some patterns.
SCI.9-12.1.5	Empirical evidence is needed to identify patterns.
SCI.9-12.2.2	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.
SCI.9-12.2.3	Systems can be designed to cause a desired effect.
SCI.9-12.2.4	Changes in systems may have various causes that may not have equal effects.
SCI.9-12.3.2	Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
SCI.9-12.3.3	Patterns observable at one scale may not be observable or exist at other scales.
SCI.9-12.3.4	Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.
SCI.9-12.3.5	Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).
SCI.9-12.6.2	The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.
SCI.9-12.7.2	Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
SCI.9-12.CCC.1.1	students observe patterns in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. They recognize classifications or explanations used at one scale may not be useful or need revision using a different scale; thus requiring improved investigations and experiments. They use mathematical representations to identify certain patterns and analyze patterns of performance in order to reengineer and improve a designed system.
SCI.9-12.CCC.2.1	students understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller scale mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects.
SCI.9-12.CCC.3.1	students understand the significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. They recognize patterns observable at one scale may not be observable or exist at other scales, and some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. Students use orders of magnitude to understand how a model at one scale relates to a model at another scale. They use algebraic thinking to examine scientific data and predict

	the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).
SCI.9-12.CCC.6.1	students investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal the system's function and/or solve a problem. They infer the functions and properties of natural and designed objects and systems from their overall structure, the way their components are shaped and used, and the molecular substructures of their various materials.
SCI.9-12.CCC.7.1	students understand much of science deals with constructing explanations of how things change and how they remain stable. They quantify and model changes in systems over very short or very long periods of time. They see some changes are irreversible, and negative feedback can stabilize a system, while positive feedback can destabilize it. They recognize systems can be designed for greater or lesser stability.
SCI.HS-PS4-2	Evaluate questions about the advantages of using a digital transmission and storage of information.
SCI.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.
SCI.HS-PS4-1	Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
SCI.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.
SCI.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.

Concepts & Formative Assessment

Part A: ***Why do physicists make the best surfers? How do we know what the inside of the Earth looks like?***

Concepts

- The wavelength and frequency of a wave 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.

Formative Assessment

Students who understand the concepts are able to:

- 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.

Resources

Wave on a string: Students will watch a wave on a string. Adjusting the amplitude, frequency, damping and tension will demonstrate wave properties.

Slinky Lab: Students will observe patterns of waves and their interactions using a slinky.

Ripple Tank: Students will investigate wave properties (speed in a medium, reflection, diffraction, interference) using the PhET virtual ripple tank, or use an actual ripple tank.

Resonance Tube: Velocity of Sound. Students will observe the resonance phenomenon in an open ended cylindrical tube, and use the resonance to determine the velocity of sound in air at ordinary temperatures.

Resonance: Students will identify, through experimentation, cause and effect relationships that affect natural resonance of these systems.

Sound Waves: Students will adjust the frequency to both see and hear how the wave changes to explain how different sounds are modeled, described, and produced.

Doppler Effect: Students will explore the detection of sound waves from a moving source and the change in frequency of the detected wave via the Doppler effect.

Refraction through Glass: Students will trace the course of different rays of light through a rectangular glass slab at different angles of incidence, measure the angle of incidence, refraction, measure the lateral displacement to verify Snell`s law.

Light box Lab: ex #2: Prism - To show how a pdsm separates white tight into its component colors and to show that different colors are refracted at different angles through a prism.

Light box Lab: ex #4:Snell's Law - To use Snell's Law to determine the index of refraction of the acrylic rhombus.

The Science Classroom

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 or, equivalently, (note that and 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 the unit on electromagnetic radiation waves more completely. Students will also explore both wave and particle models of electromagnetic radiation in the Electromagnetic Radiation Unit.

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 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 other science units

To examine an example of 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 the Unit of Plate Tectonics, relating the behavior of seismic waves to the different composition of the layers of Earth's internal structure.

Connecting with English Language Arts Literacy and Mathematics

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.

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.

Modifications

Teacher Note: Teachers identify the modifications that they will use in the unit. The unneeded modifications *can then be deleted from the list.*

- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA)
- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.

Research on Student Learning

Students who have not received any systematic instruction about light tend to identify light with its source (e.g., light is in the bulb) or its effects (e.g., patch of light). They do not have a notion of light as something that travels from one place to another. As a result, these students have difficulties explaining the direction and formation of shadows, and the reflection of light by objects. For example, some students simply note the similarity of shape between the object and the shadow or say that the object hides the light. Students often accept that mirrors reflect light but, at least in some situations, reject the idea that ordinary objects reflect light. Many students do not believe that their eyes receive light when they look at an object. Students' conceptions of vision vary from the notion that light fills space ("the room is full of light") and the eye "sees" without anything linking it to the object to the idea that light illuminates surfaces that we can see by the action of our eyes on them. The conception that the eye sees without anything linking it to the object persists after traditional instruction in optics. And some students can understand seeing as "detecting" reflected light after specially designed instruction (NSDL, 2015).

Students frequently harbor misconceptions about waves regarding frequency, period, amplitude, changing media, and wave speed (RI, 2015).

Prior Learning

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.

Connections to Other Courses

Earth and space science

- 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.

References

Adapted from the New Jesery NGSS Science Model Curriclum

Connections to NJSLS

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 address a question or solve a problem. (HS-PS4-1) **RST.11-12.7**

Mathematics

Reason abstractly and quantitatively. (HS-PS4-1) **MP.2**

Model with mathematics. (HS-PS4-1) **MP.4**

Interpret expressions that represent a quantity in terms of its context. (HS-PS4-1) **HSA-SSE.A.1**

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-SSE.B.3**

Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS4-1) **HSA.CED.A.4**