

Unit 7: The Electromagnetic Spectrum

Instructional Days: 20

Unit Summary***How do cell phones work?***

In this unit of study, students *develop and use models, use mathematical thinking, and obtain, evaluate, and communicate information* in order to describe and predict characteristic properties and behaviors of waves. Students also apply their understanding of waves as a means of sending digital information. The crosscutting concepts of *patterns* and *structure and function* are used as organizing concepts for these disciplinary core ideas. Students *develop and use models, use mathematical thinking, and obtain, evaluate, and communicate information*. Students are also expected to use these practices to demonstrate understanding of the core ideas.

This unit is based on MS-PS4-1, MS-PS4-2, and MS-PS4-3.

Student Learning Objectives

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. *[Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.]* ([MS-PS4-1](#))

Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. *[Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]* ([MS-PS4-2](#))

Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. *[Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.] [Assessment Boundary: Assessment does not include binary counting. Assessment does not include the specific mechanism of any given device.]* ([MS-PS4-3](#))

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MS-PS4-1	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-PS4-2	Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
MS-PS4-3	Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals
PS4.A	A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude
PS4.B	A wave model of light is useful for explaining brightness, color, and the frequency dependent bending of light at a surface between media
PS4.C	Digitized signals are a more reliable way to encode and transmit information

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Enduring Understandings

- When the motion energy of an object changes, there is inevitably some other change in energy at the same time.
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.
- Energy is spontaneously transferred out of hotter regions or objects and into colder

Essential Questions

- What is energy?
- How is energy conserved and transferred?
- What is the relationship between energy and forces?

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Unit Sequence	
Part A: <i>Why do surfers love physicists?</i>	
Concepts	Formative Assessments
<ul style="list-style-type: none"> • A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. • Describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. • Graphs and charts can be used to identify patterns in data. • Waves can be described with both qualitative and quantitative thinking. 	<p><i>Students who understand the concepts can:</i></p> <ul style="list-style-type: none"> • Use mathematical representations to describe and/or support scientific conclusions about how the amplitude of a wave is related to the energy in a wave. • Use mathematical representations to describe a simple model.

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Unit Sequence	
Part B: <i>How do the light and sound system in the auditorium work?</i>	
Concepts	Formative Assessments
<ul style="list-style-type: none"> • 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. • 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. • Waves are reflected, absorbed, or transmitted through various materials. • A sound wave needs a medium through which it is transmitted. • Because light can travel through space, it cannot be a matter wave, like sound or water waves. • The structure of a wave can be modified to serve particular functions by taking into account properties of different materials and how materials can be shaped and used. 	<p><i>Students who understand the concepts can:</i></p> <ul style="list-style-type: none"> • Develop and use models to describe the movement of waves in various materials.

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Unit Sequence	
Part C: <i>If rotary phones worked for my grandparents, why did they invent cell phones?</i>	
Concepts	Formative Assessments
<ul style="list-style-type: none"> • Structures can be designed to use properties of waves to serve particular functions. • Waves can be used for communication purposes. • Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information than are analog signals. • Wave-related technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations. 	<p><i>Students who understand the concepts can:</i></p> <ul style="list-style-type: none"> • Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims that digitized signals are a more reliable way to encode and transmit information than analog signals are.

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What It Looks Like in the Classroom

In this unit of study, students learn that simple waves have repeating patterns with specific wavelengths, frequencies, and amplitudes. They will use both qualitative and quantitative thinking as they describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. For example, students could use a slinky to make a small wave, then increase the energy input and observe that an increase in energy results in an increase in the amplitude of the wave. Or they could push on the surface of a container of water with different amounts of energy and observe the amplitude of the waves created inside the container. Any modeling or demonstrations used to help students visualize this should be followed up with mathematical representations that students could use as evidence to support scientific conclusions about how the amplitude of a wave is related to the energy in a wave. Students can use graphs and charts (teacher provided) to identify patterns in their data.

Students will then develop and use models to describe the movement of waves in various materials. Through the use of models and other multimedia and visual displays, students will describe that 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. Students could then broaden their understanding of wave behavior by using models to demonstrate that waves are reflected, absorbed, or transmitted through various materials. Students can observe the behavior of waves by using a penlight and tracing the path that light travels between different transparent materials (e.g., air and water, air and glass. Students could also shine a light through a prism onto a screen or piece of paper, observe a pencil in a glass of water.

A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. For example, students could observe some of the wave behaviors of light by observing that when light passes through a small opening the waves spread out. They could observe that if the wavelength is short, the waves spread out very little, whereas longer wavelengths spread out more. Students could then produce sketches of their observations. They may need some guidance in the elaboration of their sketches as it relates to the wave properties of light. Students can use a model of the electromagnetic spectrum to make connections between the brightness and color of light and the frequency of the light.

Students will continue their study of waves by observing the behavior of sound waves. Before students begin to study the behavior of sound waves, the teacher could demonstrate the importance of the presence of a medium for sound to travel. For example, if an alarm clock is placed inside a bell jar and the air is removed, the alarm will not be heard outside of the jar. Students could be asked to explain why they can hear the sound before the air is pumped out and not after. This type of demonstration could be followed by discussion of the types of media that sound passes through and how these different media

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impacts the sound.

Students could then participate in scientific discussions where they compare the behavior of mechanical waves (sound) and light waves. Based on their observations, students should be able to explain that the amplitude of all waves are related to the energy of the wave and that waves are reflected, absorbed, or transmitted through various materials. They should be able to explain that while mechanical waves need a medium in order to be transmitted, light waves do not. Therefore, because light can travel through space, it cannot be a matter wave, like sound or water waves.

Once students have a clear understanding of how different types of waves behave, they can start to explore how society utilizes those waves. The structure of a wave can be modified to serve particular functions by taking into account properties of different materials and how materials can be shaped and used. Devices have been designed to utilize properties of waves to serve particular functions. For example, cell phones use wave properties for mobile communication purposes. These devices use digitized signals (sent as wave pulses) because they are a more reliable way than analog signals to encode and transmit information (compare capacity of an LP record to a CD or MP3 player). Another example of this is how digital signals can send information over much longer distances with less loss of information because background noise can be easily converted out by the receiving devices. Wave related technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations. Students will integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims that digitized signals are a more reliable way to encode and transmit information than analog signals. Examples include basic understanding that waves can be used for communication purposes including using fiber optic cable to transmit light pulses, radio wave pulses in Wi-Fi devices, and conversation of stored binary patterns to make sound or text on a computer screen.

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Connecting with English Language Arts/Literacy and Mathematics*English Language Arts/Literacy*

- Integrate multimedia and visual displays into presentations that describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave, to clarify information.
- Integrate multimedia and visual displays into presentations of a model that describes that waves are reflected, absorbed, or transmitted through various materials to clarify information.
- Cite specific textual evidence to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.
- Determine the central ideas or conclusions of a text; provide an accurate summary of the text to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals, distinct from prior knowledge or opinions.
- Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.
- Draw evidence from informational texts to support the analysis of digitized signals as a more reliable way to encode and transmit information than analog signals.
- Integrate multimedia and visual displays into presentations to strengthen claims and evidence showing that digitized signals as a more reliable way to encode and transmit information than analog signals.

Mathematics

- Include mathematical representations to describe a simple model for waves.
- Use mathematical representations to describe and/or support scientific conclusions about how the amplitude of a wave is related to the energy in a wave.
- Understand the concept of a ratio and use ratio language to describe the relationship between the amplitude of a wave and

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the energy in the wave.

- Use ratio and rate reasoning to solve problems showing the relationship between the amplitude of a wave and the energy of the wave.
- Recognize and represent proportional relationships when using mathematical representations to describe a simple model.
- When using mathematical representations to describe a simple model, interpret the equation $y = mx + b$ as defining a linear function whose graph is a straight line and give examples of functions that are not linear.

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Modifications

(Note: Teachers identify the modifications that they will use in the unit. See NGSS Appendix D: [All Standards, All Students/Case Studies](#) for vignettes and explanations of the modifications.)

- 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.
- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA)

Research on Student Learning

N/A

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Prior Learning

By the end of Grade 5, students understand that:

- The faster a given object is moving, the more energy it possesses.
- Energy can be moved from place to place by moving objects or through sound, light, or electric currents.
- Energy is present whenever there are moving objects, sound, light, or heat.
- When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.
- Light transfers energy from place to place.
- Energy can be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by the transformation of energy of motion into electrical energy.
- Waves, which are regular patterns of motion, can be made in water by disturbing the surface.
- When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach.
- An object can be seen when light reflected from its surface enters the eyes.
- Digitized information can be transmitted over long distances without significant degradation.
- High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa.

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Future Learning

Physical science

- The wavelength and frequency of a wave are related to one another by the speed P of the wave, which depends on the type of wave and the medium through which it is passing.
- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.
- 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.
- 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.
- Photoelectric materials emit electrons when they absorb light of a high enough frequency.

Earth and space science

- The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.
- 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, by the measured composition of stars and nonstellar gases, and by maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic

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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.
- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.
- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.
- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.

Connections to Other Units**Grade 7, Unit 5: Body Systems**

- Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.

Sample of Open Education Resources

[Waves on a String](#): With this simulation (from PHeT), students explore the properties of waves and the behavior of waves through varying mediums and at reflective endpoints. There is a teacher's guide and suggested lessons on related topics that incorporate the simulation.

[Sound Waves](#): Students will learn about frequency, amplitude, how to calculate the speed of sound, and sound waves.

[Electromagnetic Math](#) is designed to supplement teaching about electromagnetism. Students explore the simple mathematics behind light and other forms of electromagnetic energy including the properties of waves, wavelength, frequency, the Doppler shift, and the various ways that astronomers image the universe across the electromagnetic spectrum to learn more about the properties of matter and its movement. This collection of 84 problems provides a variety of practical application in mathematics and science concepts including proportions, analyzing graphs, evaluating functions, the inverse-square law, parts of a wave, types of radiation, and energy. Each one-page assignment includes background information. One-page answer keys accompany the assignments.

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Appendix A: NGSS and Foundations for the Unit

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. *[Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.]* ([MS-PS4-1](#))

Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. *[Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]* ([MS-PS4-2](#))

Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. *[Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.] [Assessment Boundary: Assessment does not include binary counting. Assessment does not include the specific mechanism of any given device.]* ([MS-PS4-3](#))

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>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> Use mathematical representations to describe and/or support scientific conclusions and design solutions. (MS-PS4-1) <p>Developing and Using Models</p> <ul style="list-style-type: none"> Develop and use a model to describe 	<p>PS4.A: Wave Properties</p> <ul style="list-style-type: none"> 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) 	<p>Patterns</p> <ul style="list-style-type: none"> Graphs and charts can be used to identify patterns in data. (MS-PS4-1) <p>Structure and Function</p> <ul style="list-style-type: none"> Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be

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<p>phenomena. (MS-PS4-2)</p> <p>Obtaining, Evaluating, and Communicating Information</p> <ul style="list-style-type: none"> Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings. (MS-PS4-3) <hr/> <p style="text-align: center;">-----</p> <p style="text-align: center;">Connections to Nature of Science</p> <p>Scientific Knowledge is Based on Empirical Evidence</p> <ul style="list-style-type: none"> Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS4-1) 	<p>PS4.B: Electromagnetic Radiation</p> <ul style="list-style-type: none"> 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) <p>PS4.C: Information Technologies and Instrumentation</p> <ul style="list-style-type: none"> Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. (MS-PS4-3) 	<p>shaped and used. (MS-PS4-2)</p> <ul style="list-style-type: none"> Structures can be designed to serve particular functions. (MS-PS4-3) <hr/> <p style="text-align: center;">-----</p> <p style="text-align: center;">Connections to Engineering, Technology, and Applications of Science</p> <p>Influence of Science, Engineering, and Technology on Society and the Natural World</p> <ul style="list-style-type: none"> Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations. (MS-PS4-3) <hr/> <p style="text-align: center;">-----</p> <p style="text-align: center;">Connections to Nature of Science</p> <p>Science is a Human Endeavor</p> <ul style="list-style-type: none"> Advances in technology influence the progress of science and science has influenced advances in technology. (MS-PS4-3)
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English Language Arts	Mathematics
<p>Cite specific textual evidence to support analysis of science and technical texts. (MS-PS4-3) RST.6-8.1</p> <p>Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. (MS-PS4-3) RST.6-8.2</p> <p>Compare and contrast the information gained from experiments, simulations, videos, or multimedia sources with that gained from reading a text on the same topic. (MS-PS4-3) RST.6-8.9</p> <p>Draw evidence from informational texts to support analysis, reflection, and research. (MS-PS4-3) WHST.6-8.9</p> <p>Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-PS4-1),(MS-PS4-2) SL.8.5</p>	<p>Reason abstractly and quantitatively. (MS-PS4-1) MP.2</p> <p>Model with mathematics. (MS-PS4-1) MP.4</p> <p>Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (MS-PS4-1) 6.RP.A.1</p> <p>Use ratio and rate reasoning to solve real-world and mathematical problems. (MS-PS4-1) 6.RP.A.3</p> <p>Recognize and represent proportional relationships between quantities. (MS-PS4-1) 7.RP.A.2</p> <p>Interpret the equation $y = mx + b$ as defining a linear function, whose graph is a straight line; give examples of functions that are not linear. (MS-PS4-1) 8.F.A.3</p>

Common Vocabulary	
<p>Conservation</p> <p>Convert</p> <p>Current</p> <p>Electric circuit</p> <p>Electric current</p> <p>Transfer</p>	<p>Mass</p> <p>Design task</p> <p>Field</p> <p>Insulate</p> <p>Evolve</p> <p>Systematic</p>