Unit 7 2018. Electromagnetic Radiation

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Enduring Understandings

- Light is an electromagnetic wave that stimulates the retina of the eye.
- Light travels in a straight line through any uniform medium.
- Electromagnetic radiation can be used to transfer information across long distances, store information, and be used to investigate nature on many scales.
- Electromagnetic radiation can be modeled as a wave or a particle.
- The electromagnetic spectrum is divided based on the frequency of the waves.
- All types of light travel at the same speed when in the same medium.
- 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.
- 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.
- Solar cells are human-made devices that capture the sun’s energy and produce electrical energy.
- 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.
- Photoelectric materials emit electrons when they absorb light of a high enough frequency.
- Engineers continuously modify technological systems for transmission and storage of information by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.
- Electromagnetic waves are integrated into our everyday lives.

Essential Questions

- How can electromagnetic radiation be both a wave and a particle at the same time?

- What are the pros and cons of digital transmission and storage of information?
- How do astronauts on the International Space Station survive and communicate with earth?
- How does light interact with matter?

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

- Students will differentiate between the different types of electromagnetic radiation..
- Students will discuss how technology uses electromagnetic radiation.
- Characterize electromagnetic waves; what they are and how they are produced.
- Evaluate how electromagnetic waves transfer energy.
- Classify electromagnetic waves by their frequency and wavelength
- Describe characteristics of visible light

- **Performance Expectations**
- **Evaluate questions about the advantages of using a digital transmission and storage of information.** *[Clarification Statement: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.]* **(HS-PS4-2)**

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-PS4-3)**

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-PS4-4)**

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.]* **(HS-PS4-5)**

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. (HS-ETS1-1)

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. (HS-ETS1-3)

Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. (HS-ESS2-2)

Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. (HS-ESS2-4)

Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. (HS-ETS1-4)

Create interactive data visualizations using software tools to help others better understand real world phenomena, including climate change. (8.1.12.DA.1)

Science and Engineering Practices

Engaging in Argument from Evidence

- 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

- 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)

Asking Questions and Defining Problems

- Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1)
- 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)

Constructing Explanations and Designing Solutions

- Evaluate a solution to a complex real world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)

Disciplinary Core Ideas

PS4.A: Wave Properties

- 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)
- 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. (HS-PS4-5)
- 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. (HS-PS4-2)

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-PS45)

PS3.D: Energy in Chemical Processes

- Solar cells are human-made devices that likewise capture the sun’s energy and produce electrical energy. (secondary to 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)

ETS1.A: Defining and Delimiting Engineering Problems

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1)

ETS1.B: Developing Possible Solutions

- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)
- Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)

ESS2.D: Weather and Climate

- The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS-ESS2-2)(HS-ESS2-4)
- Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS-ESS2-6),(HS-ESS2-7)
- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-6),(HS-ESS2-4)

Computer Science and Design Thinking

Individuals select digital tools and design automated processes to collect, transform, generalize, simplify and present large data sets in different ways to influence how other people interpret and understand the underlying information.

Crosscutting Concepts

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 systems at different scales. (HS-PS4-3)

Cause and Effect

- 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)
- Systems can be designed to cause a desired effect. (HS-PS4-5)

Stability and Change

- Systems can be designed for greater or lesser stability. (HS-PS4-2)
- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS2-7)
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS2-1)
- Feedback (negative or positive) can stabilize or destabilize a system. (HS-ESS2-2)

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, HS-PS4-2)
- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-3)
- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HSPS4-2)

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 have been repeatedly confirmed through observation and experiment. 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)

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.9-12.3.3	Patterns observable at one scale may not be observable or exist at other scales.
SCI.9-12.4.2	When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.
SCI.9-12.4.3	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.

SCI.9-12.5.5	In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.
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.5.1	students learn that the total amount of energy and matter in closed systems is conserved. They can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. They also learn that energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.
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-ESS1-3	Communicate scientific ideas about the way stars, over their life cycle, produce elements.
SCI.HS-ESS1-1	Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.
SCI.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.
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.
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-PS4-2	Evaluate questions about the advantages of using a digital transmission and storage of information.
SCI.HS-PS2-5	Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.
SCI.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 position of particles (objects).
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.

Resources

Light Box Lab: Ex#5 Total Internal Reflection - To determine the critical angle at which total internal reflection occurs and to confirm it using Snell's Law.

Introduction to the Electromagnetic Spectrum: NASA background resource

Technology for Imaging the Universe: NASA background resource

NASA LAUNCHPAD: Making Waves: NASA e-Clips activity on the electromagnetic spectrum

Radio Waves and Electromagnetic Fields: Phet simulation demonstrating wave generation, propagation and detection with antennas.

Refraction: https://phet.colorado.edu/en/simulation/wave-interferencePHeT simulation addressing refraction of light at an interface.

Wave Interference: Phet simulation of both mechanical and optical wave phenomena

Thin Film Interference: OSP simulation of thin film interference for various wavelengths of visible light

Photoelectric Effect Phet: (uses Java) Phet simulation addressing evidence for particle nature of electromagnetic radiation

Photoelectric Effect (uses Java) OSP: Open Source Physics simulation of the photoelectric effect.

Interaction of Molecules with Electromagnetic Radiation: Phet simulation exploring the effect of microwave, infrared, visible and ultraviolet radiation on various molecules.

Blackbody Spectrum: Phet simulation

Greenhouse Effect: Phet simulation

Wave/Particle Dualism: Phet simulation of wave and particle views of interference phenomena.

X-ray Technology: OSP Simulation of optimization of X-ray contrast by varying energy of X-rays, materials characteristics and measurement parameters

Physics 2000: Socratic development of knowledge of electromagnetic radiation

NASA: Global Climate Change Vital Signs of the Planet: Real-data that can be analyzed

New Jersey Climate Change Education Hub: Resources to teach climate change

Modeling Incoming Solar Radiation: NASA resource that helps students trace the solar energy once it gets to the Earth

Actively Learn:

The Electromagnetic Spectrum (https://reader.activelylearn.com/authoring/preview/763684)

Clarkson University: Greenhouse Effect (https://www.clarkson.edu/stem/project-based-climate-modules/greenhouse-effect)