Developing and Using Science and Engineering Practices (by Lesson)

SEP Element #	Lesson	Elements of Science and Engineering Practice(s)	Rationale
1.2	6	Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.	Students ask questions that arise from examining reflective properties in the microwave oven walls and door. Students also identify categories of unanswered questions from the Driving Question Board.
1.2	9	Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.	Students examine the model of the electromagnetic spectrum to ask questions that seek additional information about the uses and interactions with matter of different types of EM radiation.
1.4	1	Ask questions to clarify and refine a model, an explanation, or an engineering problem.	Students ask questions to clarify and refine their models of how microwave radiation transfers energy to food, and why the structure of the microwave oven is designed in such a way as to affect wireless communication signals.
1.4	4	Ask questions to clarify and refine a model, an explanation, or an engineering problem.	Students ask questions to clarify and refine a model of energy transfer from the antenna to distant electrons.
1.4	8	Ask questions to clarify and refine a model, an explanation, or an engineering problem.	Students develop questions that arise from examining the revised class consensus model and the Driving Question Board to clarify and refine the relationships between electromagnetic radiation and matter.
2.3	1	Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.	Students develop a model based on their prior knowledge and experiences to illustrate how energy transfers from the components of a microwave oven to the liquid/food in it. They revise this model after receiving feedback from a peer.
2.3	5	Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.	Students use models developed in Lesson 4 and revise them with their predictions of how microwave radiation interacts with parts of the microwave oven system. The class develops an energy transfer model to illustrate where the energy is going in the oven in a control condition. Students then use that model to individually develop a new model representing energy transfer in the system and how radiation interacts with different types of matter (through absorption, reflection, and/or transmission) in one of the experimental conditions, based on the evidence collected in the whole-class investigations.
2.3	7	Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.	Students briefly develop a physical model of water molecules responding to changing fields, and identify the model's limitations. Primarily, they use a simulation to model several particle types (neutral polar, neutral nonpolar, negative charge) interacting with microwave radiation, and they use both models to co-construct a model of molecule interactions with changing fields.

SEP Element #	Lesson	Elements of Science and Engineering Practice(s)	Rationale
2.3	8	Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.	Students develop and use a model based on evidence to explain the role of interference and to make inferences about heat distribution in the microwave oven.
2.4	4	Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.	Students use multiple types of models of electromagnetic radiation to provide mechanistic accounts of how electric and magnetic waves propagate through space.
2.4	6	Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.	In the transfer task, students use a model of matter-energy interactions in Earth's atmosphere to provide a mechanistic explanation about the cause-and-effect relationship between the concentration of greenhouse gases in the atmosphere and the increase in global temperature.
2.6	12	Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.	Students use a simulation to develop and test a coding system for transferring information using EM waves, and then work as a class to develop a consensus model of the system representing how information flow is mediated by changes in the motion of electrons (matter) in antennas and energy transfers through EM radiation. They use this model to organize their response to a summary of the lesson question.
3.1	1	Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.	Students brainstorm investigations that they would like to do to answer their questions about the microwave oven and related technology.
3.1	5	Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.	Students collaboratively plan investigations to produce data to serve as evidence as part of building and revising models and to support explanations of a phenomenon. They consider possible confounding variables or effects and evaluate the investigations' design to ensure variables are controlled when they complete the investigation planning handout.
3.2	3	Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	Students plan and conduct an investigation on how the controllable variables in the Waves on a String simulation affect other variables. They use their findings as evidence to consider how this connects to how much energy transfers through the wave.
3.3	5	Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.	Students plan revised investigations to meet the agreed-upon safety considerations when they complete the investigation planning handout.

SEP Element #	Lesson	Elements of Science and Engineering Practice(s)	Rationale
4.5	10	Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.	Students use slinkies from Lesson 3 to consider how amplitude and frequency could lead to increases in energy of EM radiation. Then they read through excerpts from medical literature to collect new data about how energy in high-amplitude and high-frequency EM radiation affects humans, learning that increases in frequency cause more damage than increases in amplitude. This new data does not make sense, so students revise their understanding of a model to explain the process of ionization due to higher frequencies of EM radiation. They use new information about a photon model of light to better explain their evidence.
5.3	3	Apply techniques of algebra and functions to represent and solve scientific and engineering problems.	Students apply algebraic techniques to their data from their investigation to test their mathematical model of frequency, wave speed, and wavelength.
6.1	3	Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.	Students make claims about how changing various wave properties affects the energy transferred by a wave.
6.2	4	Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, 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.	The class develops an explanatory model of energy transfer from an antenna through electromagnetic radiation.
7.2	10	Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.	Students consider an analogy model for light as a wave to conclude that this model does not match our evidence for amplitude and frequency, and then they read about a photon model. They evaluate which evidence is better explained by the photon model and/or the wave model, and summarize their conclusions. They determine that though both models have merits and can explain different aspects of the behavior of waves, the photon model better fits the evidence in this circumstance, because the wave model is limited in its ability to explain the connection between high frequency and ionization.
7.3	13	Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions.	In the transfer task, students provide a respectful critique on a social media post by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions.
7.4	9	Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.	Students construct a written argument based on evidence about the relationship between the frequency and wavelength of EM radiation and its interactions with matter, and how this relationship helps explain some of the uses of EM radiation, and present it orally to a peer.

SEP Element #	Lesson	Elements of Science and Engineering Practice(s)	Rationale
8.1	11	Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.	Students critically read scientific literature adapted for classroom use to determine how X-ray technology works, what its benefits and risks are, and how to minimize those risks.
8.2	2	Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.	Students read a handout about a magnetron and integrate it with other sources of information (a video made by a young engineer, a diagram from our manual showing the parts of the microwave oven, and evidence from a class demonstration) to answer questions about changing electric fields.
8.2	12	Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.	Students integrate multiple sources of information from four information stations presented in different media or formats (e.g., visually, quantitatively) as well as in words to provide an answer to the question, "How are our wireless electronic devices designed to use EM waves to reliably communicate different types of information?"
8.2	13	Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.	Students discuss answers to Driving Question Board questions, using information from prior investigations.
8.4	7	Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.	Students evaluate the validity and reliability of multiple claims that appear in media reports, and they suggest ways to verify the claims empirically.
8.4	13	Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.	In the transfer task, students evaluate two claims given in social media posts, considering reliability and validity and using the criteria they applied in earlier lessons with the checklist scaffold.

Developing and Using Crosscutting Concepts (by Lesson)

CCC Elements #	Lesson	Elements of Crosscutting Concept(s)	Rationale
1.1	10	Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.	Students consider how various examples of EM radiation affect skin cancer risk in humans, then look for patterns in the data to conclude that higher frequency tends to be more dangerous than higher amplitude and leads to the microscopic event of ionization. This pattern is unique to the chart, as the macroscopic slinky activity had comparable increases in energy from increasing the frequency and increasing the amplitude of the wave.

CCC Elements #	Lesson	Elements of Crosscutting Concept(s)	Rationale
1.4	3	Mathematical representations are needed to identify some patterns.	Students use mathematical reasoning and representations to identify the pattern that connects frequency, wave speed, and wavelength.
1.5	4	Empirical evidence is needed to identify patterns	Students identify different patterns in electric fields by collecting empirical data with compasses to provide evidence for causality in explanations of how electromagnetic waves propagate through space.
2.1	6	Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.	In the transfer task, students use empirical data, either provided in the assessment or from experiments we have done in class, to support their cause-and-effect explanations about the relationships between the concentration of greenhouse gases and global temperature.
2.2	4	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.	Students examine what is known about electric field and magnetic field propagation through space to explain how energy transfers from an antenna to distant charged particles.
2.2	7	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.	Students identify that the charge distribution of a particle affects how it interacts with a changing electric field. They use the interactions between changing fields and both polar and nonpolar particles to explain observed changes in temperature at a macroscopic scale.
2.2	8	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.	Students suggest cause-and-effect relationships between wave interference and heat distribution inside the microwave oven by examining force interactions between two waves.
2.2	10	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.	Through learning about the photon model, students conclude that EM radiation only tends to cause ionization if each individual photon has sufficient energy to eject an electron. This explains why IR light doesn't cause current from a solar cell and why visible light tends not to increase skin cancer risk.
2.2	13	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.	Students answer a reflection question designed to get them thinking about how our investigations over the course of this unit help us predict macroscopic cause-and-effect relationships by examining smaller-scale mechanisms within the system. They also apply this reasoning in the transfer task.
2.3	12	Systems can be designed to cause a desired effect.	Students explain how computers can translate binary code to and from text, audio, video, and location information, and how wireless messages are designed so that only the intended receiver can decode the information (encrypted).

CCC Elements #	Lesson	Elements of Crosscutting Concept(s)	Rationale
4.1	2	Systems can be designed to do specific tasks.	Students refer to specific design features of a magnetron and a microwave oven to explain how the motion of electrons in an antenna generates changing electric fields in the oven.
4.1	9	Systems can be designed to do specific tasks.	Students use quantitative and qualitative information to identify how the properties of EM radiation can be harnessed for various applications, such as medical imaging, telecommunications, and energy production.
4.3	12	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.	Students use a computer model to develop and test a coding system for transferring information using EM waves. They develop a class consensus model of this system. They use a slinky spring (physical model) to simulate information transfer with digital code using frequency-key and amplitude-key modulated signals at one of four stations and interpret graphs that represent these two signal structures.
5.1	5	The total amount of energy and matter in closed systems is conserved.	Students use the idea that energy is conserved as they use a model to explain why (1) a bowl of water that is not covered increases in temperature in a microwave oven, but a bowl of water that is covered with foil (with or without holes) does not and (2) a bowl of water that is only partly covered with foil shows a greater temperature increase in the uncovered portion of the water than in the covered portion.
5.2	1	Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.	Students create models that describe matter changes and energy transfer in a microwave oven as it heats liquid/food, and when it affects wireless signals (such as those between an electronic device and a Bluetooth speaker).
5.2	3	Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.	Students use their data to consider how energy transfer across a wave system can be described by changes in matter in the string and changes in energy in the bonds between the string particles.
5.2	5	Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.	Students use a model to represent energy transfer paths into, out of, and within various parts of the microwave oven system. Paths within the modeled system indicate different matter interactions (reflection versus absorption) for different parts of the system to account for changes in the water's thermal energy in different conditions.
5.2	6	Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.	In the transfer task, students analyze the flow of energy into Earth's atmosphere and back out of Earth's surface, and the energy flows within Earth's atmosphere, to explain the increase in global temperatures over the last century.

CCC Elements #	Lesson	Elements of Crosscutting Concept(s)	Rationale
5.2	8	Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.	Students revise their initial consensus model from the anchor phenomenon to include showing how energy is transferred within the microwave oven.
5.3	8	Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.	Students use wave interference to explore the idea that the energy transferred through electromagnetic radiation is not created or destroyed--it only moves between one place and another place inside the microwave oven.
6.1	2	Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.	Students investigate the structure of a magnetron, a component of a microwave oven, to reveal its function (moving electrons in an antenna).
6.1	11	Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.	Students read about radiography to explore how EM radiation and its interactions with different materials can be used to create and store digital information.
6.1	13	Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.	Students answer a reflection question designed to get them thinking about how our investigations over the course of this unit help us understand how the properties of different materials and the structures of different components can affect the way a technology functions.
6.2	1	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	Students consider how we can answer our questions about the structure and function of designed objects (a Bluetooth speaker, a wireless device, and a microwave oven).
6.2	6	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	Students develop new questions to continue investigating the relationship between the structure/shape of the microwave oven and its interactions with various types of matter.
6.2	7	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	Students explain how the polar and nonpolar structure of molecules can account for temperature and heating differences as food is exposed to changing fields in microwave ovens. They also read about how electrons moving freely throughout aluminum can cause large electric fields to build up at the edges of metal, which can cause arcing.
6.2	8	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	Students investigate how the structure of the microwave oven influences energy transfer through wave interference, and use the revised class consensus model to make inferences about the role of the oven's turntable.

Disciplinary Core Ideas (by Lesson)

DCI Elements #	Lesson	Elements of Disciplinary Core Idea(s)	Rationale
ESS2.A.3	6	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. (HS-ESS2-4)	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~~. (See above for explanation of partial coverage.)
ESS2.D.1	6	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-ESS2-4)	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.
PS2.B.2	7	Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-4),(HS-PS2-5)	Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. ~~Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.~~ (HS-PS2-4, HS-PS2-5)
PS3.A.1	5	Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HSPS3-1),(HS-PS3-2)	Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
PS3.A.4	3	These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)	These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles). ~~This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.~~ (HS-PS3-2)
PS3.D.1	5	Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3),(HS-PS3-4)	Although energy cannot be destroyed, it can be converted to less useful forms--for example, to thermal energy in the surrounding environment.
PS4.A.1	3	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)	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)

DCI Elements #	Lesson	Elements of Disciplinary Core Idea(s)	Rationale
PS4.A.1	13	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)	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)
PS4.A.2	11	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),(HSPS4-5)	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~~.
PS4.A.2	12	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),(HSPS4-5)	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.
PS4.A.3	8	[From the 3–5 grade band endpoints] 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)	Waves can add or cancel each other 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. (HS-PS4-3)
PS4.B.1	2	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)	Electromagnetic radiation (e.g., ~~radio,~~ microwave radiation~~, 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)
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PS4.B.1	4	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)	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)
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PS4.B.2	1	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)	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)
PS4.B.2	5	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)	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.~~
PS4.B.2	6	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)	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)~~
PS4.B.2	7	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)	When light or longer wavelength electromagnetic radiation is absorbed into 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)
PS4.B.2	8	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)	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)
PS4.B.2	9	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)	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)

DCI Elements #	Lesson	Elements of Disciplinary Core Idea(s)	Rationale
PS4.B.2	10	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)	~~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.
PS4.B.2	13	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)	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)
PS4.B.3	10	Photovoltaic materials emit electrons when they absorb light of a high-enough frequency. (HS-PS4-5)	Photovoltaic materials emit electrons when they absorb light of a high-enough frequency.
PS4.C.1	1	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)	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)
PS4.C.1	8	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)	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)
PS4.C.1	9	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)	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)
PS4.C.1	11	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)	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.

DCI Elements #	Lesson	Elements of Disciplinary Core Idea(s)	Rationale
PS4.C.1	12	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)	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.
PS4.C.1	13	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)	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)