Evidence Statements

*Resources to compile this document came from NGSS Evidence statements for PS for more grades and standards required for the Utah SEEd. Please review the NGSS Evidence statements and decide what is best for your demographics of students.

Objectives for PHYSICS 1st Quarter

FORCES AND INTERACTIONS		
PHYS.1.1 Analyze and interpret data to determine the cause and effect relationship between the net force on an object and its change in motion as summarized by Newton's Second Law of Motion. Emphasize one-dimensional motion and macroscopic objects moving at non-relativistic speeds. Examples could include objects subject to a net unbalanced force, such as a falling object, an object sliding down a ramp, or a moving object being pulled by a constant force. (PS2.A)		
1.1.1 - Organize Data	Students organize data that represent the net force on a macroscopic object, its mass (which is held constant), and its acceleration (e.g., via tables, graphs, charts, vector drawings).	
1.1.2 Identify a Relationship	Students use tools, technologies, and/or models to analyze the data and identify relationships within the datasets, including: i. A more massive object experiencing the same net force as a less massive object has a smaller acceleration, and a larger net force on a given object produces a correspondingly larger acceleration; and ii. The result of gravitation is a constant acceleration on macroscopic objects as evidenced by the fact that the ratio of net force to mass remains constant.	
1.1.3 - INTERPRET	Students use the analyzed data as evidence to describe* that the relationship between the observed quantities is accurately modeled across the range of data by the formula a = Fnet/m (e.g., double force yields double acceleration, etc.).	
1.1.4 - INTERPRET	Students use the data as empirical evidence to distinguish between causal and correlational relationships linking force, mass, and acceleration	
1.1.5 - INTERPRET	Students express the relationship Fnet=ma in terms of causality, namely that a net force on an object causes the object to accelerate.	
1.1.6 INVESTIGATE	Students identify the purpose of the investigation, which includes providing evidence that the change in an object's motion is due to the following factors: a. Balanced or unbalanced forces acting on the object b. The mass of the object.	
1.1.7 INVESTIGATE	Students develop a plan for the investigation individually or collaboratively. In the plan, students describe: a. That the following data will be collected:Data on the motion of the object, Data on the total forces acting on the object, Data on the mass of the object. b. Which data are needed to provide evidence for each of the following: An object subjected to balanced forces does not change its motion (sum of F=0). An object subjected to unbalanced forces changes its motion over time (sum of F≠0). The change in the motion of an object subjected to unbalanced forces depends on the mass of the object.	
1.1.8	In the investigation plan, students describe:	

INVESTIGATE	a. How the following factors will be determined and measured: i. The motion of the object, including a specified reference frame and appropriate units for distance and time. ii. The mass of the object, including appropriate units. iii. The forces acting on the object, including balanced and unbalanced forces. b. Which factors will serve as independent and dependent variables in the investigation (e.g., mass is an independent variable, forces and motion can be independent or dependent). c. The controls for each experimental condition. d. The number of trials for each experimental condition.	
1.1.9 - MODEL	Students create and identify net forces that are acting upon objects	
1.1.10 - RELATIONSHIP	Students identify that more massive object experiencing the same net force as a less massive object has a smaller acceleration, and a larger net force on a given object produces a correspondingly larger acceleration.	
1.1.11 - RELATIONSHIP	Students identify that the result of gravitation is a constant acceleration on macroscopic objects as evidenced by the fact that the ratio of net force to mass remains constant	
PHYS.1.2 Use mathematics and computational thinking to support the claim that the total momentum of a system is conserved when there is no net force acting on the system. Emphasize the quantitative conservation of momentum in interactions and the qualitative meaning of this principle. Examples could include one-dimensional elastic or inelastic collisions between objects within the system. (PS2.A)		
1.2.1 - Representation	Students clearly define the system of the two interacting objects that is represented mathematically, including boundaries and initial conditions.	
1.2.2- Representation	Students identify and describe* the momentum of each object in the system as the product of its mass and its velocity, $p = mv$ (p and v are restricted to one-dimensional vectors), using the mathematical representations.	
1.2.3 - Representation	Students identify the claim, indicating that the total momentum of a system of two interacting objects is constant if there is no net force on the system	
1.2.4 - MATH	Students use the mathematical representations to model and describe* the physical interaction of the two objects in terms of the change in the momentum of each object as a result of the interaction.	
1.2 MATH	Students use the mathematical representations to model and describe* the total momentum of the system by calculating the vector sum of momenta of the two objects in the system.	
1.2 ANALYSIS	Students use the analysis of the motion of the objects before the interaction to identify a system with essentially no net force on it.	
1.2 ANALYSIS	Based on the analysis of the total momentum of the system, students support the claim that the momentum of the system is the same before and after the interaction between the objects in the system, so that momentum of the system is constant.	
1.2 - ANALYSIS	Students identify that the analysis of the momentum of each object in the system indicates that any change in momentum of one object is balanced by a	

	change in the momentum of the other object, so that the total momentum is constant.	
PHYS.1.3 Design a solution that has the function of minimizing the impact force on an object during a collision. Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize a solution. Emphasize problems that require application of Newton's Second Law of Motion or conservation of momentum. (PS2.A, ETS1.A, ETS1.B, ETS1.C)		
1.3 - DESIGN SOLUTION	Students design a device that minimizes the force on a macroscopic object during a collision. In the design...	
1.3 - DESIGN SOLUTION	Incorporate the concept that for a given change in momentum, force in the direction of the change in momentum is decreased by increasing the time interval of the collision ($F\Delta t = m\Delta v$); and	
1.3 - DESIGN SOLUTION	Explicitly make use of the principle above so that the device has the desired effect of reducing the net force applied to the object by extending the time the force is applied to the object during the collision.	
1.3 - DESIGN SOLUTION	In the design plan, students describe* the scientific rationale for their choice of materials and for the structure of the device.	
1.3 C and C	Students describe* and quantify (when appropriate) the criteria and constraints, along with the tradeoffs implicit in these design solutions. Examples of constraints to be considered are cost, mass, the maximum force applied to the object, and requirements set by society for widely used collision-mitigation devices (e.g., seatbelts, football helmets).	
1.3 EVALUATE	Students systematically evaluate the proposed device design or design solution, including describing* the rationales for the design and comparing the design to the list of criteria and constraints.	
1.3 EVALUATE	Students test and evaluate the device based on its ability to minimize the force on the test object during a collision. Students identify any unanticipated effects or design performance issues that the device exhibits.	
1.3 REFINE	Students use the test results to improve the device performance by extending the impact time, reducing the device mass, and/or considering cost-benefit analysis	

Objectives for PHYSICS 2nd Quarter

ENERGY		
PHYS.2.1 Analyze and interpret data to track and calculate the transfer of energy within a system. Emphasize the identification of the components of the system, along with their initial and final energies, and mathematical descriptions to depict energy transfer in the system. Examples of energy transfer could include the transfer of energy during a collision or heat transfer.(PS3.1)		
2.1.1 - REPRESENT	Students identify and describe* the components to be computationally modeled, including:	

2.1.2 I	i.The boundaries of the system and that the reference level for potential energy = 0 (the potential energy of the initial or final state does not have to be zero);	
2.1.3	ii. The initial energies of the system's components (e.g., energy in fields, thermal energy, kinetic energy, energy stored in springs — all expressed as a total amount of Joules in each component), including a quantification in an algebraic description to calculate the total initial energy of the system;	
2.1.4	iii. The energy flows in or out of the system, including a quantification in an algebraic description with flow into the system defined as positive; and	
2.1.5	iv.The final energies of the system components, including a quantification in an algebraic description to calculate the total final energy of the system.	
2.1.6 - MATH MODELING	Students use the algebraic descriptions of the initial and final energy state of the system, along with the energy flows to create a computational model (e.g., simple computer program, spreadsheet, simulation software package application) that is based on the principle of the conservation of energy.	
2.1.7 - MATH MODELING	Students use the computational model to calculate changes in the energy of one component of the system when changes in the energy of the other components and the energy flows are known.	
2.1.8 - ANALYSIS	Students use the computational model to predict the maximum possible change in the energy of one component of the system for a given set of energy flows.	
2.1.9 - ANALYSIS	Students identify and describe* the limitations of the computational model, based on the assumptions that were made in creating the algebraic descriptions of energy changes and flows in the system.	
Standard PHYS.2.2 **Plan and conduct an investigation** to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system. Emphasize that uniform distribution of energy is a natural tendency. Examples could include the measurement of the reduction of temperature of a hot object or the increase in temperature of a cold object. (PS3.4)		
2.2.1 PHEN	Students describe* the purpose of the investigation, which includes the following idea, that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).	
2.2.2 QUESTION	Students develop an investigation plan and describe* the data that will be collected and the evidence to be derived from the data, including: a. The measurement of the reduction of temperature of the hot object and the increase in temperature of the cold object to show that the thermal energy lost by the hot object is equal to the thermal energy gained by the cold object and that the distribution of thermal energy is more uniform after the interaction of the hot and cold components; and b. The heat capacity of the components in the system (obtained from scientific literature).	
2.2.3 INVEST	In the investigation plan, students describe*: a. How a nearly closed system will be constructed, including the	

	boundaries and initial conditions of the system; b. The data that will be collected, including masses of components and initial and final temperatures; and c. The experimental procedure, including how the data will be collected, the number of trials, the experimental set up, and equipment required.	
2.2.4 DATA	Students collect and record data that can be used to calculate the change in thermal energy of each of the two components of the system.	
2.2.5 EVALUATE	Students evaluate their investigation, including: a. The accuracy and precision of the data collected, as well as the limitations of the investigation; and b. The ability of the data to provide the evidence required.	
2.2.6 REFINE	If necessary, students refine the plan to produce more accurate, precise, and useful data that address the experimental question.	
2.2.7 IDENTIFY	Students identify potential causes of the apparent loss of energy from a closed system (which should be zero in an ideal system) and adjust the design of the experiment accordingly.	
2.2.1 - MODELING	Students develop models in which they identify and describe* the relevant components, including:	
2.2.2- MODELING	All the components of the system and the surroundings, as well as energy flows between the system and the surroundings;	
2.2.3 - MODELING	Clearly depicting both a macroscopic and a molecular/atomic-level representation of the system; and two interacting objects is constant if there is no net force on the system	
2.2.4 - MODELING	Depicting the forms in which energy is manifested at two different scales: a. Macroscopic , such as motion, sound, light, thermal energy, potential energy or energy in fields; and b. Molecular/atomic, such as motions (kinetic energy) of particles (e.g., nuclei and electrons), the relative positions of particles in fields (potential energy), and energy in fields	
2.2.5 RELATIONSHIP	Students describe* the relationships between components in their models, including:	
2.2.6 RELATIONSHIP	Changes in the relative position of objects in gravitational, magnetic or electrostatic fields can affect the energy of the fields (e.g., charged objects moving away from each other change the field energy).	
2.2.7 RELATIONSHIP	Thermal energy includes both the kinetic and potential energy of particle vibrations in solids or molecules and the kinetic energy of freely moving particles (e.g., inert gas atoms, molecules) in liquids and gases	
2.2.8 RELATIONSHIP	Students use the analysis of the motion of the objects before the interaction to identify a system with essentially no net force on it.	

2.2.9 RELATIONSHIP	The total energy of the system and surroundings is conserved at a macroscopic and molecular/atomic level.	
2.2.10 RELATIONSHIP	Chemical energy can be considered in terms of systems of nuclei and electrons in electrostatic fields (bonds).	
2.2.11 RELATIONSHIP	As one form of energy increases, others must decrease by the same amount as energy is transferred among and between objects and fields.	
2.2.12 CONNECT	Students use their models to show that in closed systems the energy is conserved on both the macroscopic and molecular/atomic scales so that as one form of energy changes, the total system energy remains constant, as evidenced by the other forms of energy changing by the same amount or changes only by the amount of energy that is transferred into or out of the system.	
2.2.13 CONNECT	Students use their 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 positions of particles/objects on both the macroscopic and microscopic scales.	

Standard PHYS.2.3 **Develop and use models** on the macroscopic scale to illustrate that energy can be accounted for as a combination of energies associated with the motion of objects and energy associated with the relative positions of objects. Emphasize relationships between components of the model to show that energy is conserved. Examples could include mechanical systems where kinetic energy is transformed to potential energy or vice versa. (PS3.2)		
2.3.1 - MODEL	Students develop models in which they identify and describe* the relevant components, including:	
2.3.2 MODEL	i.All the components of the system and the surroundings, as well as energy flows between the system and the surroundings;	
2.3.3 MODEL	ii. Clearly depicting both a macroscopic and a molecular/atomic-level representation of the system; and	
2.3.4 MODEL	iii. Depicting the forms in which energy is manifested at two different scales: a. Macroscopic , such as motion, sound, light, thermal energy, potential energy or energy in fields; and b. Molecular/atomic, such as motions (kinetic energy) of particles (e.g., nuclei and electrons), the relative positions of particles in fields (potential energy), and energy in fields.	
2.3.5 RELATION	Students describe* the relationships between components in their models, including:	
2.3.6 RELATION	i.Changes in the relative position of objects in gravitational, magnetic or electrostatic fields can affect the energy of the fields (e.g., charged objects moving away from each other change the field energy).	
2.3.7 RELATION	ii. Thermal energy includes both the kinetic and potential energy of particle vibrations in solids or molecules and the kinetic energy of freely moving particles (e.g., inert gas atoms, molecules) in liquids and gases.	
2.3.8 RELATION	iii.The total energy of the system and surroundings is conserved at a macroscopic and	

	molecular/atomic level.	
2.3.9 RELATION	iv. Chemical energy can be considered in terms of systems of nuclei and electrons in electrostatic fields (bonds).	
2.3.10 RELATION	v. As one form of energy increases, others must decrease by the same amount as energy is transferred among and between objects and fields	
2.3.11 CONNECT	Students use their models to show that in closed systems the energy is conserved on both the macroscopic and molecular/atomic scales so that as one form of energy changes, the total system energy remains constant, as evidenced by the other forms of energy changing by the same amount or changes only by the amount of energy that is transferred into or out of the system.	
2.3.12 CONNECT	Students use their 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 positions of particles/objects on both the macroscopic and microscopic scales	
Standard PHYS.2.4 **Design a solution** by constructing a device that converts one form of energy into another form of energy to solve a complex real-life problem. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize a solution*. Examples of energy transformation could include electrical energy to mechanical energy, mechanical energy to electrical energy, or electromagnetic radiation to thermal energy. (PS3.3, ETS1.A, ETS1.B, ETS1.C)		
2.4.1 - DESIGN	Students design a device that converts one form of energy into another form of energy.	
2.4.2- DESIGN	Students develop a plan for the device in which they: a. Identify what scientific principles provide the basis for the energy conversion design; b. Identify the forms of energy that will be converted from one form to another in the designed system; c. Identify losses of energy by the design system to the surrounding environment; d. Describe* the scientific rationale for choices of materials and structure of the device, including how student-generated evidence influenced the design; and e. Describe* that this device is an example of how the application of scientific knowledge and engineering design can increase benefits for modern civilization while decreasing costs and risk.	
2.4.3 - C and C	Students describe* and quantify (when appropriate) prioritized criteria and constraints for the design of the device, along with the tradeoffs implicit in these design solutions. Examples of constraints to be considered are cost and efficiency of energy conversion.	
2.4.4 EVALUATE	Students build and test the device according to the plan.	
2.4.5 EVALUATE	Students systematically and quantitatively evaluate the performance of the device against the criteria and constraints	
2.4.6 REFINE	Students use the results of the tests to improve the device performance by	

	increasing the efficiency of energy conversion, keeping in mind the criteria and constraints, and noting any modifications in tradeoffs	

Standard PHYS 2.5 **Design a solution** to a major global problem that accounts for societal energy needs and wants. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data to make improvements from iteratively testing solutions, and optimize a solution*. Emphasize problems that require the application of conservation of energy principles through energy transfers and transformations. Examples of devices could include one that uses renewable energy resources to perform functions currently performed by nonrenewable fuels or ones that are more energy efficient to conserve energy. (PS3.A, PS3.B, PS3.D, ETS1.A, ETS1.B, ETS1.C)			
2.5.1 - DESIGN	Students design a device that converts one form of energy into another form of energy.		
2.5.2- DESIGN	Students develop a plan for the device in which they: a. Describe* the system being impacted and how the human activity is affecting that system; b. Identify the scientific knowledge and reasoning on which the solution is based; c. Describe* how the technological solution functions and may be stabilizing or destabilizing the natural system; d. Refine a given technological solution that reduces human impacts on natural systems; and e. Describe* that the solution being refined comes from scientists and engineers in the real world who develop technologies to solve problems of environmental degradation.		
2.5.3 - C and C	The tradeoffs in the solution, considering priorities and other kinds of research-driven tradeoffs in explaining why this particular solution is or is not needed. Examples of constraints to be considered are cost and efficiency of energy conversion.		
2.5.4 EVALUATE	In their evaluation, students describe* how the refinement will improve the solution to increase benefits and/or decrease costs or risks to people and the environment.		
2.5.5 EVALUATE	Students evaluate the proposed refinements for: a. Their effects on the overall stability of and changes in natural systems; and b. Cost, safety, aesthetics, and reliability, as well as cultural and environmental impacts.		

Objectives for PHYSICS 3rd Quarter

FIELDS	
Standard PHYS.3.1 **Use mathematics and computational thinking** to compare the scale and proportion of gravitational and electric fields using Newton's Law of Gravitation and Coulomb's Law. Emphasize the	

parative strength of these two field forces, the effect of distance between interacting cts on the magnitudes of these forces, and the use of models to understand field forces. 2.B)		
3.1.1 REPRESENT	Students clearly define the system of the interacting objects that is mathematically represented.	
3.1.2 MATH	Using the given mathematical representations, students identify and describe* the gravitational attraction between two objects as the product of their masses divided by the separation distance squared (Fg = −G m1m2 d2), where a negative force is understood to be attractive.	
3.1.3 MATH	Using the given mathematical representations, students identify and describe* the electrostatic force between two objects as the product of their individual charges divided by the separation distance squared (Fe = k q1q2 d2), where a negative force is understood to be attractive	
3.1.4 MATH MODEL	Students correctly use the given mathematical formulas to predict the gravitational force between objects or predict the electrostatic force between charged objects.	
3.1.5 ANALYSIS	Based on the given mathematical models, students describe* that the ratio between gravitational and electric forces between objects with a given charge and mass is a pattern that is independent of distance.	
3.1.6 ANALYSIS	Students describe* that the mathematical representation of the gravitational field (Fg = −G m1m2 d2) only predicts an attractive force because mass is always positive.	
3.1.7 ANALYSIS	Students describe* that the mathematical representation of the electric field (Fe = k q1q2 d2) predicts both attraction and repulsion because electric charge can be either positive or negative.	
3.1.8 ANALYSIS	Students use the given formulas for the forces as evidence to describe* that the change in the energy of objects interacting through electric or gravitational forces depends on the distance between the objects.	
Standard PHYS.3.2 Plan and conduct an investigation to provide evidence that an electric current causes a magnetic field and that a changing magnetic field causes an electric current. Emphasize the qualitative relationship between electricity and magnetism without necessarily conducting quantitative analysis. Examples could include electromagnets or generators. (PS2.C)		
3.2.1 PHEN	Students describe* the phenomenon under investigation, which includes the following idea: that an electric current produces a magnetic field and that a changing magnetic field produces an electric current.	
3.2.1 QUESTION	Students develop an investigation plan and describe* the data that will be collected and the evidence to be derived from the data about 1) an observable effect of a magnetic field that is uniquely related to the presence of an electric current in the circuit, and 2) an electric current in the circuit that is uniquely related to the presence of a changing magnetic field near the circuit. Students describe* why these effects seen must be causal and not correlational, citing specific cause-effect relationships.	

3.2.2 INVEST	In the investigation plan, students include: a. The use of an electric circuit through which electric current can flow, a source of electrical energy that can be placed in the circuit, the shape and orientation of the wire, and the types and positions of detectors; b. A means to indicate or measure when electric current is flowing through the circuit; c. A means to indicate or measure the presence of a local magnetic field near the circuit; and d. A design of a system to change the magnetic field in a nearby circuit and a means to indicate or measure when the magnetic field is changing.	
3.2.3 INVEST	In the plan, students state variables and controls	
3.2.3 DATA	Students measure and record electric currents and magnetic fields.	
3.2.4 EVALUATE	Students evaluate their investigation, including an evaluation of: i. The accuracy and precision of the data collected, as well as limitations of the investigation; and ii. The ability of the data to provide the evidence required.	
3.2.5 REFINE	If necessary, students refine the investigation plan to produce more accurate, precise, and useful data such that the measurements or indicators of the presence of an electric current in the circuit and a magnetic field near the circuit can provide the required evidence.	

Standard PHYS.3.3 **Analyze and interpret data** to compare the effect of changes in position of interacting objects on electric and gravitational forces and energy. Emphasize the similarities and differences between charged particles in electric fields and masses in gravitational fields. Examples could include models, simulations, or experiments that produce data or illustrate field lines between objects. (PS3.C, PS3-5)			
3.3.1	Students formulate questions that arise from examining given data of objects (which can include particles) interacting through electric and magnetic forces, the answers to which would clarify:		
3.3.2	The cause-and-effect relationships that affect magnetic forces due to: 1. The magnitude of any electric current present in the interaction, or other factors related to the effect of the electric current (e.g., number of turns of wire in a coil). 2. The distance between the interacting objects. 3. The relative orientation of the interacting objects. 4. The magnitude of the magnetic strength of the interacting objects.		
3.3.3	The cause-and-effect relationship that affect electric forces due to: 1. The magnitude and signs of the electric charges on the interacting objects. 2. The distances between the interacting objects. 3. Magnetic forces.		
3.3.4	Based on scientific principles and given data, students frame hypotheses that can be used to distinguish between possible outcomes, based on an understanding of the cause-and-effect relationships driving the system		

Standard PHYS.3.4 **Develop and use a model** to evaluate the effects on a field as characteristics of its source and surrounding space are varied. Emphasize how a field changes with distance from its source. Examples of electric fields could include those resulting from point charges. Examples of magnetic fields could include those resulting from dipole magnets or current-bearing wires. (PS3.C)			
3.4 MODEL	Students develop a model in which they identify and describe* the relevant components to illustrate the forces and changes in energy involved when two objects interact, including: i. The two objects in the system, including their initial positions and velocities (limited to one dimension). ii. The nature of the interaction (electric or magnetic) between the two objects. iii. The relative magnitude and the direction of the net force on each of the objects. iv. Representation of a field as a quantity that has a magnitude and direction at all points in space and which contains energy.		
3.4 RELATIONSHIP	a. In the model, students describe* the relationships between components, including the change in the energy of the objects, given the initial and final positions and velocities of the objects.		
3.4 CONNECT	Students use the model to determine whether the energy stored in the field increased, decreased, or remained the same when the objects interacted.		
3.4 CONNECT	Students use the model to support the claim that the change in the energy stored in the field (which is qualitatively determined to be either positive, negative, or zero) is consistent with the change in energy of the objects.		
3.4 CONNECT	Using the model, students describe* the cause and effect relationships on a qualitative level between forces produced by electric or magnetic fields and the change of energy of the objects in the system.		

Objectives for PHYS.4

WAVES		
Standard PHYS.4.1 **Analyze and interpret data** to derive both qualitative and quantitative relationships based on patterns observed in frequency, wavelength, and speed of waves traveling in various media. Emphasize mathematical relationships and qualitative descriptions. Examples of data could include electromagnetic radiation traveling in a vacuum or glass, sound waves traveling through air or water, or seismic waves traveling through Earth. (PS4.A)		
Phenomena	**Supports Students in Demonstrating Proficiency:** ● The sound made when you blow across the top of a straw changes when you shorten the straw. ● A bonfire and a campfire are the same color. ● When lighting strikes, there is time in-between when we see the lightning and when we hear the thunder. ● When a fire engine drives by, the sound changes as it approaches and goes away.	
4.1.1 - REPRESENT	Students identify and describe* the relevant components in the mathematical representations: i. Mathematical values for frequency, wavelength, and speed of waves traveling in various specified media; and ii. The relationships between frequency, wavelength, and speed of waves traveling in various specified media	
4.1.2 MATH	Students show that the product of the frequency and the wavelength of a particular type of wave in a given medium is constant, and identify this relationship as the wave speed according to the mathematical relationship $v = f\lambda$.	
	Students use the data to show that the wave speed for a particular type of wave changes as the medium through which the wave travels changes.	
4.1 Analysis	a Using the mathematical relationship $v = f\lambda$, students assess claims about any of the three quantities when the other two quantities are known for waves travelling in various specified media. b Students use the mathematical relationships to distinguish between cause and correlation with respect to the supported claims.	
4.1 Mathematical Modeling	Students predict the relative change in the wavelength of a wave when it moves from one medium to another (thus different wave speeds using the mathematical relationship $v = f\lambda$). Students express the relative change in terms of cause (different media) and effect (different wavelengths but same frequency).	
	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.	
DCI	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.	

HELP	**Sentence stems that utilize academic language:** ● The following predictions can be made about _______ when using the pattern of _______ found in the data. ● I/We can observe (notice) the pattern of _______ in the data presented. ● The pattern seen in the collected data allows me/us to conclude (know) that _______. ● The observed pattern supports the conclusion that _______ is caused by _______, because _______. **Words to support student discourse related to the Disciplinary Core Ideas (DCIs):** Simple wave, frequency, wavelength, vacuum, properties of waves, electromagnetic radiation, radiation, wave source, angle of incidence, angle of reflection, normal, interface, refraction.	
Competency	**What does it look like to demonstrate proficiency on this standard?** **Representation** Students identify and describe the relevant components in the mathematical representations: ● Mathematical values for frequency, wavelength, and speed of waves traveling in various specified media ● The quantitative relationships between frequency, wavelength, and speed of waves traveling in various specified media. ● The qualitative relationships between frequency, wavelength, and speed of waves traveling in various specified media. **Mathematical modeling** Students use mathematical models based on data to ● Show that the product of the frequency and the wavelength of a particular type of wave in a given medium is constant ● Identify the constant relationship between frequency and wavelength as the wave speed according to the mathematical relationship $v = f\lambda$. ● Show that the wave speed for a particular type of wave changes as the medium through which the wave travels changes. ● Predict the relative change in the wavelength of a wave when it moves from one medium to another (thus different wave speeds using the mathematical relationship $v = f\lambda$). ● Express the relative change of speed in terms of cause (different media) and effect (different wavelengths but same frequency). **Analysis** Students use the mathematical relationship $v = f\lambda$: ● assess claims about any of the three quantities when the other two quantities are known for waves travelling in various specified media. ● distinguish between cause and correlation with respect to the supported claims.	

Standard PHYS.4.2 **Engage in argument based on evidence** that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model better explains interactions within a system than the other. Emphasize how the experimental evidence supports the claim and how models and explanations are modified in light of new evidence.

Examples could include resonance, interference, diffraction, or the photoelectric effect. (PS4.A, PS4.B)		
PHENOMENA	• Underneath trees, there are lots of circular light spots, even though the gaps in the tree above are not circular. Some spots are brighter than others • Spectroscopy • Light charging materials- solar panels	
	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.]	
4.2 CER	a. Students identify the given explanation that is to be supported by the claims, evidence, and reasoning to be evaluated, and that includes the following idea: Electromagnetic radiation can be described either by a wave model or a particle model, and for some situations one model is more useful than the other	
4.2 CER	b.Students identify the given claims to be evaluated.	
4.2 CER	C. Students identify the given evidence to be evaluated, including the following phenomena: i. Interference behavior by electromagnetic radiation; and ii. The photoelectric effect.	
4.2 CER	D. Students identify the given reasoning to be evaluated.	
4.2 Evaluating given evidence and reasoning	a Students evaluate the given evidence for interference behavior of electromagnetic radiation to determine how it supports the argument that electromagnetic radiation can be described by a wave model.	
4.2	b Students evaluate the phenomenon of the photoelectric effect to determine how it supports the argument that electromagnetic radiation can be described by a particle model.	
4.2	c Students evaluate the given claims and reasoning for modeling electromagnetic radiation as both a wave and particle, considering the transfer of energy and information within and between systems, and why for some aspects the wave model is more useful and for other aspects the particle model is more useful to describe the transfer of energy and information.	
DCI	PS4.A: Wave Properties [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.)	

DCI	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.	
HELP	**Sentence stems that utilize academic language:** ● The key components of the system are _______ and they work together by _______. ● In the system, _______ and _______ are shown in the model. ● In the system, _______ is not shown in the model. This is not shown because _______. ● The key assumptions to the model of my system are _______ this affects the reliability of the model because _______. ● The (particle/wave)model was chosen to represent _______ because of _______. **Words to support student discourse related to the Disciplinary Core Ideas (DCIs):** Electromagnetic spectrum, wave properties, resonance, interference, wavelength, crest, trough, amplitude, reflection, refraction, mechanical waves, speed of light, medium, photon, photon energy	
Competency	**What does it look like to demonstrate proficiency on this standard?** **Identifying the given explanation and associated claims, evidence, and reasoning** Students identify the given explanation that includes the following idea: ● Electromagnetic radiation can be described either by a wave model or a particle model, and for some situations one model is more useful than the other. Students identify the given ● claims to be evaluated as to whether the wave model or particle model is more useful. ● evidence to be evaluated, including the following phenomena ○ Interference behavior by electromagnetic radiation ○ The photoelectric effect ● identify the given reasoning to be evaluated **Evaluating given evidence and reasoning** Students evaluate the given ● evidence for interference behavior of electromagnetic radiation to determine how it supports the argument that electromagnetic radiation can be described by a wave model. ● phenomenon of the photoelectric effect to determine how it supports the argument that electromagnetic radiation can be described by a particle model. ● claims and reasoning for modeling electromagnetic radiation as both a wave and particle, considering the transfer of energy and information within and between systems, and why for some aspects the wave model is more useful and for other aspects the particle model is more useful to describe the transfer of energy and information.	

Standard PHYS.4.3 **Evaluate information** about the effects that different frequencies of electromagnetic radiation have when absorbed by biological

materials. Emphasize that the energy of electromagnetic radiation is directly proportional to frequency and that the potential damage to living tissue from electromagnetic radiation depends on the energy of the radiation. (PS4.B)		
	Phenomena that Supports Students in Demonstrating Proficiency: ● The symbol of the international Radura logo is used to show a food has been treated with ionizing radiation. If you saw this on your food would it worry you at all? Would you think it is safe to eat the food? ● My mother told me my earbuds would give me a brain tumor.	
4.3 Obtaining information	a Students obtain at least two claims proposed in published material (using at least two sources per claim) regarding the effect of electromagnetic radiation that is absorbed by matter. One of these claims deals with the effect of electromagnetic radiation on living tissue.	
4.3 Evaluating Information	a Students use reasoning about the data presented, including the energies of the photons involved (i.e., relative wavelengths) and the probability of ionization, to analyze the validity and reliability of each claim. b Students determine the validity and reliability of the sources of the claims. c Students describe* the cause and effect reasoning in each claim, including the extrapolations to larger scales from cause and effect relationships of mechanisms at small scales (e.g., extrapolating from the effect of a particular wavelength of radiation on a single cell to the effect of that wavelength on the entire organism).	
	[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.]	
DCI	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	
HELP	**Sentence stems that utilize academic language:** ● If _______ happens, I/we predict that ________ will occur. ● Even though I/we cannot see _______, it explains why _______ is happening. ● The evidence _______ presented in the scenario supports the claim that _______ causes _______. ● In order to conclude that _______ caused _______, the following evidence is needed _______. ● **Words to support student discourse related to the Disciplinary Core Ideas (DCIs):** Electromagnetic radiation, wavelength, frequency, speed of light, Photon energy, media, photon, tissues, cells, organism	
Competency	**What does it look like to demonstrate proficiency on this standard?**	

<table>
<tr><td></td><td>Obtaining information
Students obtain at least two claims proposed in published material (using at least two sources per claim) regarding:
● the effect of electromagnetic radiation that is absorbed by matter.
● one of these claims deals with the effect of electromagnetic radiation on living tissue.
Evaluating information
Students describe whether the gathered information is relevant for determining:
● the cause and effect reasoning in each claim, including the extrapolations to larger scales from cause and effect relationships of mechanisms at small scales (e.g., extrapolating from the effect of a particular wavelength of radiation on a single cell to the effect of that wavelength on the entire organism).
Students determine the credibility, accuracy, usefulness, and possible bias of each source of information of including:
● The ideas included and the methods described
● Sources are published literature
● Comparing different sources
Students use reasoning to analyze the validity and reliability of each claim based on data that includes:
● the energies of the photons involved (i.e., relative wavelengths)
● the probability of ionization
Communication style and format
Students use at least two different formats (oral, graphical, textual and mathematical) to communicate scientific and technical information including:
● the effect of electromagnetic radiation that is absorbed by biological matter</td><td></td></tr>
<tr><td colspan="3">Standard PHYS.4.4 Ask questions and construct an explanation about the <u>stability</u> of digital transmission and storage of information and their impacts on society. Emphasize the stability of digital signals and the discrete nature of information transmission. Examples of stability and instability could include that digital information can be stored in computer memory, is transferred easily, copied and shared rapidly can be easily deleted, has limited fidelity based on sampling rates, or is vulnerable to security breaches and theft. (PS4.A)</td></tr>
<tr><td></td><td>Phenomena that Supports Students in Demonstrating Proficiency:
● My grandparents played music on a record player that used vinyl records.
● Cell phones can send and transmit information in a variety of ways.
● Analog versus Digital Television</td><td></td></tr>
<tr><td>4.4
Communication style and format</td><td>: a Students use at least two different formats (e.g., oral, graphical, textual, and mathematical) to communicate technical information and ideas, including fully describing* at least two devices and the physical principles upon which the devices depend. One of the devices must depend on the photoelectric effect for its operation. Students cite the origin of the information as appropriate.</td><td></td></tr>
</table>

<table>
<tr><td>4.4
Connecting the DCIs and the CCCs</td><td>a. When describing* how each device operates, students identify the wave behavior utilized by the device or the absorption of photons and production of electrons for devices that rely on the photoelectric effect, and qualitatively describe* how the basic physics principles were utilized in the design through research and development to produce this functionality (e.g., absorbing electromagnetic energy and converting it to thermal energy to heat an object; using the photoelectric effect to produce an electric current).
b For each device, students discuss the real-world problem it solves or need it addresses, and how civilization now depends on the device.
c Students identify and communicate the cause and effect relationships that are used to produce the functionality of the device.</td><td></td></tr>
<tr><td>DCI</td><td>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.</td><td></td></tr>
<tr><td></td><td>Sentence stems that utilize academic language:
● The system described in the scenario is (stable/unstable). The evidence to support my claim is _______.
● The factors that cause this system to be(stable/unstable) are _______.
● This system is affected in the long term by _______.

Words to support student discourse related to the Disciplinary Core Ideas (DCIs):
Wavelength, frequency, electromagnetic waves, crest, trough, amplitude, square waves, modulation, analog, digital</td><td></td></tr>
<tr><td></td><td>What does it look like to demonstrate proficiency on this standard?
Asking Questions
Addressing phenomena of the natural world or scientific theories
Students evaluate the given questions in terms of whether or not answers to the questions would:
● Provide examples of features associated with digital transmission and storage of information. For example
○ can be stored reliably without degradation over time
○ transferred easily, and copied and shared rapidly
○ can be easily deleted
○ can be stolen easily by making a copy
○ can be broadly accessed
In their evaluation of the given questions, students:
● Describe the stability and importance of the systems that employ digital information as they relate to the advantages and disadvantages of digital transmission and storage of information
● Discuss the relevance of the answers to the question to real-life examples. For example
○ emailing your homework to a teacher
○ copying music
○ using the internet for research
○ social media
Evaluating empirical testability
Students evaluate the given questions in terms of whether or not answers to the questions would provide means to empirically determine
● whether given features are advantages or disadvantages.</td><td></td></tr>
</table>

	Constructing an Explanation **Articulating the explanation of phenomena** Students construct an explanation that includes: ● The stability of a digital transmission and storage of information. It could include ○ That digital information can be stored in computer memory, is transferred easily, copied and shared rapidly be easily deleted, has limited fidelity based on sampling rates, or is vulnerable to security breaches and theft. ● The impacts on society ● The discrete nature of information **Evidence** Students identify and describe the evidence of features associated with digital transmission and storage of information to construct the explanation, including how information can: ● be stored reliably without degradation over time ● transferred easily, and copied and shared rapidly ● be easily deleted ● be stolen easily by making a copy ● be broadly accessed Students use a variety of valid and reliable sources for the evidence, which may include ● theories, simulations, peer review, students' own investigations, and multiple technologies **Reasoning** Students use reasoning to connect evidence to construct their explanation to describe the stability and importance of the systems that employ digital information as they relate to the advantages and disadvantages of digital transmission and storage of information to answer the real-life examples. For example ● emailing your homework to a teacher ● copying music ● using the internet for research ● social media **Revising the explanation** Given new data or information about the features associated with digital transmission and storage of information, ● students revise their explanation and justify the revision	

Standard PHYS.4.5 Obtain, evaluate, and communicate information about how devices use the principles of electromagnetic radiation and their interactions with matter to transmit and capture information and energy. Emphasize the ways in which devices leverage the wave- particle duality of electromagnetic radiation. Examples could include solar cells, medical imaging devices, or communication technologies. (PS4.A, PS4.B, PS4.C)

	Phenomena that Supports Students in Demonstrating Proficiency:		

	• Communication towers are found throughout our cities and on mountaintops. Radio, TV stations, and cell phones use these. • Solar Cars		
4.5 Communication style and format	a Students use at least two different formats (e.g., oral, graphical, textual, and mathematical) to communicate technical information and ideas, including fully describing* at least two devices and the physical principles upon which the devices depend. One of the devices must depend on the photoelectric effect for its operation. Students cite the origin of the information as appropriate.		
4.5 Connecting the DCIs and the CCCs	a When describing* how each device operates, students identify the wave behavior utilized by the device or the absorption of photons and production of electrons for devices that rely on the photoelectric effect, and qualitatively describe* how the basic physics principles were utilized in the design through research and development to produce this functionality (e.g., absorbing electromagnetic energy and converting it to thermal energy to heat an object; using the photoelectric effect to produce an electric current).		
4.5	For each device, students discuss the real-world problem it solves or need it addresses, and how civilization now depends on the device.		
4.5	Students identify and communicate the cause and effect relationships that are used to produce the functionality of the device.		
DCI	PS3.D: Energy in Chemical Processes Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (secondary)		
DCI	PS4.A: Wave Properties 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		
DCI	PS4.B: Electromagnetic Radiation Photoelectric materials emit electrons when they absorb light of a high-enough frequency.		
DCI	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.		
	Sentence stems that utilize academic language: • The matter ________ as it interacts with the energy. • The flow of energy causes the matter to ________. • The atoms ________ in response to the energy. **Words to support student discourse related to the Disciplinary Core Ideas (DCIs):** Frequency, wavelength, electromagnetic radiation, photon, photon energy		
	What does it look like to demonstrate proficiency on this standard? **Obtaining information**		

	Students gather information from published, grade-level appropriate material from at least two sources (literature, media, visual displays, data) about how devices: ● use the principles of electromagnetic radiation ● use the principles of how electromagnetic radiation interacts with matter to ○ To transmit information and energy ○ To capture information and energy ● Leverage the wave-particle duality of electromagnetic radiation **Evaluating information** Students determine and describe whether the gathered information is relevant for determining how the device: ● Interacts with matter to transmit and capture information and energy ● Leverages the wave-particle duality of electromagnetic radiation Students determine the credibility, accuracy, usefulness, and possible bias of each source of information of including: ● The ideas included and the methods described ● Sources are published literature ● Comparing different sources Students synthesize information that is presented in various modes (graphs, diagrams, photographs, text, mathematical, verbal) to describe: ● How devices leverage the wave-particle duality of electromagnetic radiation to interact with matter to ○ Transmit information and energy ○ Capture information and energy **Communication style and format** Students use at least two different formats (oral, graphical, textual and mathematical) to communicate scientific and technical (information, ideas) including: ● at least two devices and the physical principles upon which the devices depend. ● one of the devices must depend on the photoelectric effect for its operation. ● Students cite the origin of the information as appropriate. **Connecting the DCIs and the CCCs** Students identify and communicate evidence for wave behavior including how: ● the wave behavior utilized by the device or the absorption of photons and production of electrons for devices that rely on the photoelectric effect ● the basic physics principles were utilized in the design through research and development to produce this functionality for example ○ absorbing electromagnetic energy and converting it to thermal energy to heat an object ○ using the photoelectric effect to produce an electric current ● the device solves the real-world problem and how civilization now depends on the device ● the cause and effect relationships that are used to produce the functionality of the device.		