Performance Expectation *and Louisiana Connectors*
HS-PS2-2 Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. ***LC-HS-PS2-2a Identify an example of the law of conservation of momentum (e.g., in a collision, the momentum change of an object is equal to and opposite of the momentum change of the other object) represented using graphical or visual displays (e.g., pictures, pictographs, drawings, written observations, tables, charts).***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Analyzing and interpreting data: Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. ***Analyze data using tools in order to make valid and reliable scientific claims.*** ***Analyze data using tools in order to determine an optimal design solution.*** ***Analyze data using technology in order to make valid and reliable scientific claims.***	**FORCES AND MOTION** Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS.PS2.A.a) ***Unbalanced forces applied to an object will cause acceleration.*** ***The size of this acceleration is determined by the mass of the object and the size of force applied.*** ***Forces might change the motion of objects (e.g., During tug-of-war, if forces on opposite teams are equal, the rope will not move.).*** ***Forces change the motion of objects. Newton's Laws can be used to predict these changes.*** ***Newton's second law describes the effects of the size of the total force and the object's mass on its resulting acceleration.*** ***The reason why objects may react differently to equal sized forces is explained by Newton's second law.***	**CAUSE AND EFFECT** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. ***Evidence is required when attributing an observed phenomenon to a specific cause.*** ***Evidence is required to explain the causal mechanisms in a system under study.*** ***Evidence is required to support a claim about the causal mechanisms in a system under study.***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Analyze data using technology in order to determine an optimal design solution. ***Analyze data using models in order to make valid and reliable scientific claims.*** ***Analyze data using models in order to determine an optimal design solution.***		

Clarification Statement	
Physical Science	Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force. Emphasis is on one-dimensional motion and macroscopic objects moving at nonrelativistic speeds.
Chemistry	Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force. Emphasis is on kinematics, one-dimensional motion, two-dimensional motion, and macroscopic objects moving at non-relativistic speeds.

Performance Expectation *and Louisiana Connectors*
HS-PS2-2 Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. ***LC-HS-PS2-2a Identify an example of the law of conservation of momentum (e.g., in a collision, the momentum change of an object is equal to and opposite of the momentum change of the other object) represented using graphical or visual displays (e.g., pictures, pictographs, drawings, written observations, tables, charts).***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Using mathematics and computational thinking: Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions, including, computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. ***Use mathematical or algorithmic forms for scientific modeling of phenomena to describe claims.*** ***Use mathematical or algorithmic***	**FORCES AND MOTION** Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. In any system, total momentum is always conserved. (HS.PS2A.b) ***Momentum is the product of an object's mass and its velocity.*** ***Momentum is determined by the speed of an object and the direction it is traveling (velocity) of an object and the object's mass.*** ***The momentum of an object is in the same direction as its velocity.*** ***The more momentum an object has, the harder it is to stop.*** ***The Law of Conservation of Momentum can be used to predict the outcomes of collisions between objects and can aid in understanding the energy transfers and energy transformations in these collisions.*** If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS.PS2A.c) ***Momentum is conserved as long as there are no new objects added to the system.*** ***The total momentum of any group of objects remains the same unless outside forces act on the object.*** ***Only unbalanced forces can change the momentum of an object.*** ***An impulse represents how much the momentum of an object changes when a force acts on it over a period of time.***	**SYSTEMS AND SYSTEM MODELS** When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. ***Making models helps people understand things they cannot observe directly.*** ***Scientists use models to represent things that are either very large or very small.*** ***Any model of a system incorporates assumptions and approximations (e.g., the boundaries and initial conditions of the***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
forms for scientific modeling of design solutions to describe claims. *Use mathematical or algorithmic forms for scientific modeling of phenomena to support claims.* *Use mathematical or algorithmic forms for scientific modeling of design solutions to support claims.* *Use mathematical or algorithmic forms for scientific modeling of phenomena to describe explanations.* *Use mathematical or algorithmic forms for scientific modeling of design solutions to describe explanations.* *Use mathematical or algorithmic forms for scientific modeling of phenomena to support explanations.* *Use mathematical or algorithmic forms for scientific modeling of design solutions to support explanations.*	*The impulse describes the relationship between the force acting on an object and the change it produces in the object's momentum.*	*system, inputs and outputs).* *It is critical to be aware of a system's physical, chemical, biological, and social interactions and how they affect the model's reliability and precision.*

Clarification Statement	
Physical Science	Emphasis is on calculating momentum and the qualitative meaning of conservation of momentum.
Chemistry	Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle as well as systems of two macroscopic bodies moving in one dimension.

Performance Expectation *and Louisiana Connectors*
HS-PS2-3 Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. ***LC-HS-PS2-3a Evaluate a device (e.g., football helmet or a parachute) designed to minimize force by comparing data (i.e., momentum, mass, velocity, force, or time).***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Constructing explanations and designing solution: Constructing explanations (science) and designing solutions (engineering) in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. ***Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.*** ***Evaluate a solution to a complex real-world problem, based on***	**FORCES AND MOTION** If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS.PS2A.c) ***Momentum is conserved as long as there are no new objects added to the system.*** ***The total momentum of any group of objects remains the same unless outside forces act on the object.*** ***Only unbalanced forces can change the momentum of an object.*** ***An impulse represents how much the momentum of an object changes when a force acts on it over a periods of time.*** ***The impulse describes the relationship between the force acting on an object and the change it produces in the object's momentum.*** **DEFINING AND DELIMITING ENGINEERING PROBLEMS** Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS.ETS1A.a) ***A first step in designing a device to solve a problem is prioritizing criteria and constraints for the design of the device.*** ***The social, economic, and political forces of a society have a significant influence on what science and technology solutions are implemented.*** **OPTIMIZING THE DESIGN SOLUTION** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (HS.ETS1C.a)	**CAUSE AND EFFECT** Systems can be designed to cause a desired effect. ***It is important to describe the design of a solution and the features that make it successful.*** ***An intentional change to a system can cause a desired effect.***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. ***Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.***	***It is important to prioritize the benefits and costs of the design of a solution to a problem. The decision as to which criteria are critical and which ones can be traded off is a judgment based on the situation and the needs of the system.***	

Clarification Statement	
Physical Science	Examples of evaluation and refinement could include determining the success of a device at protecting an object from damage such as, but not limited to, impact resistant packaging and modifying the design to improve it. Emphasis is on qualitative evaluations.
Chemistry	Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it by applying the impulse-momentum theorem. Examples of a device could include a football helmet or an airbag. Emphasis is on qualitative evaluations and/or algebraic manipulations.

Performance Expectation *and Louisiana Connectors*
HS-PS2-4 Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. ***LC-HS-PS2-4a Use Newton's law of universal gravitation as a mathematical model to qualitatively describe or predict the effects of gravitational forces in systems with two objects.*** ***LC-HS-PS2-4b Use Coulomb's law to qualitatively describe or predict the electrostatic forces in systems with two objects.***

Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concept**
Using mathematics and computational thinking: Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions (e.g., trigonometric, exponential and logarithmic) and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. ***Use mathematical or algorithmic forms for scientific modeling of phenomena to describe claims.*** ***Use mathematical or algorithmic***	**TYPES OF INTERACTIONS** Newton's Law of Universal Gravitation and Coulomb's Law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between objects not in physical contact. (HS.PS2B.a) ***Gravitational, electric, and magnetic forces between a pair of objects do not require that they be in contact.*** ***These forces are explained by force fields that contain energy and can transfer energy through space.*** ***Gravitational force is a universal force of attraction that acts between masses, but this force is only significant when one (or both) of the objects is massive (for example, a star, planet or moon).*** ***Newton's Law of Universal Gravitation provides the mathematical model to describe and predict the effects of gravitational forces between distant objects.*** ***Electric forces and magnetic forces are different aspects of a single electromagnetic interaction.*** ***Coulomb's law provides the mathematical model to describe and predict the effects of electrostatic forces (relating to stationary electric charges or fields) between distant objects*** ***Attractive or repulsive forces between objects are relative to their charges and the distance between them (Coulombs Law).*** 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.PS2B.b) ***Moving electric charges produce magnetic fields; changing magnetic fields induce electric currents.***	**PATTERNS** 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. ***Patterns can be used to explain phenomena.*** ***Different patterns can be observed at different scales (micro and macro) in a system.*** ***Classifications used at one scale may fail or need revision when information from smaller or larger scales is introduced.***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
forms for scientific modeling of design solutions to describe claims. *Use mathematical or algorithmic forms for scientific modeling of phenomena to support claims.* *Use mathematical or algorithmic forms for scientific modeling of design solutions to support claims.* *Use mathematical or algorithmic forms for scientific modeling of phenomena to describe explanations.* *Use mathematical or algorithmic forms for scientific modeling of design solutions to describe explanations.* *Use mathematical or algorithmic forms for scientific modeling of phenomena to support explanations.* *Use mathematical or algorithmic forms for scientific modeling of design solutions to support explanations.*	*An electric field is the field around a charged particle that exerts a force on other charged particles.* *A magnetic field is a region around a magnet in which a magnetic force acts. (It is not always an attraction, sometimes it is a repulsion.)* *Moving electric charges produce magnetic fields.* *Electrical energy carried by currents in wires can be used to create magnetic fields.* *Magnets and rotating coils can be used to create electric currents.*	

Clarification Statement
Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.

Performance Expectation ***and Louisiana Connectors***
HS-PS2-5 Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. ***LC-HS-PS2-5a Identify situations and provide evidence where an electric current is producing a magnetic field.*** ***LC-HS-PS2-5b Identify situations and provide evidence where a magnetic field is producing an electric current.***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Planning and carrying out Investigations: Planning and carrying out investigations to answer questions or test solutions to problems in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • 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. ***Plan an investigation individually and collaboratively to produce data to serve as the basis for evidence,***	**TYPES OF INTERACTIONS** Forces that act over 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.PS2B.b) ***Moving electric charges produce magnetic fields; changing magnetic fields induce electric currents.*** ***An electric field is the field around a charged particle that exerts a force on other charged particles.*** ***A magnetic field is a region around a magnet in which magnetic attraction acts.*** ***Gravity is the force which pulls objects together.*** ***Moving electric charges produce magnetic fields.*** ***Electrical energy carried by currents in wires can be used to create magnetic fields.*** ***Magnets and rotating coils can be used to create electric currents.*** **DEFINITIONS OF ENERGY** "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (HS.PS3A.d) ***Electrical energy is a form of energy that can be transferred by moving charges through a complete circuit.*** ***A battery is a combination of two or more electrochemical cells in a series.*** ***Batteries are portable sources of electrical energy.***	**CAUSE AND EFFECT** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. ***Evidence is required when attributing an observed phenomenon to a specific cause.*** ***Evidence is required to explain the causal mechanisms in a system under study.*** ***Evidence is required to support a claim about the causal mechanisms in a system under study.***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements. ***Revise an investigation individually and collaboratively to produce data to serve as the basis for evidence.*** ***Conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence.***		

Clarification Statement	
Physical Science	Emphasis is on designing and conducting investigations including evaluating simple series and parallel circuits. Qualitative evidence is used to explain the relationship between a current-carrying wire and a magnetic compass.
Chemistry	Evidence of changes within a circuit can be represented numerically, graphically, or algebraically using Ohm's law. Emphasis is on designing and conducting investigations using qualitative evidence to determine the relationship between electric current and magnetic fields. Examples of evidence can include movement of a magnetic compass needle when placed in the vicinity of a current-carrying wire, and a magnet passing through a coil that turns on the light of a Faraday flashlight.

Performance Expectation *and Louisiana Connectors*
HS-PS3-1 Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. ***LC-HS-PS3-1a Identify a model showing the change in the energy of one component in a system compared to the change in energy of another component in the system.*** ***LC-HS-PS3-1b Identify a model showing the change in energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Using mathematics and computational thinking: Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including, computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. ***Create a computational model of a phenomenon.*** ***Revise a computational model of a phenomenon.*** ***Create a simulation of a***	**DEFINITIONS OF ENERGY** 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. (HS.PS3A.a) ***Energy is the ability to do work or cause change.*** ***Energy transforms from one form to another, but these transformations are not always reversible.*** ***A system's total energy is conserved regardless of the transfers within the system.*** ***The total energy of a system changes only by the amount of energy transferred into and out of the system.*** **CONSERVATION OF ENERGY AND ENERGY TRANSFER** Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS.PS3B.a) ***The law of conservation of energy states that when one form of energy is converted to another, no energy is destroyed in the process.*** ***According to the law of conservation of energy, energy cannot be created or destroyed.*** ***The total change of energy in any system is always equal to the total energy transferred into or out of the system.***	**SYSTEMS AND SYSTEM MODELS** Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. ***Models can be valuable in predicting a system's behaviors.*** ***Any model of a system incorporates assumptions and approximations.*** ***As a result, model-based predictions have limited precision and reliability.***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
phenomenon. ***Revise a simulation of a phenomenon.*** ***Create a computational model of a designed device.*** ***Revise a computational model of a designed device.*** ***Create a simulation of a designed device.*** ***Revise a simulation of a designed device.*** ***Create a computational model of a process.*** ***Revise a computational model of a process.*** ***Create a simulation of a process.*** ***Revise a simulation of a process.*** ***Create a computational model of a system.*** ***Revise a computational model of a system.*** ***Create a simulation of a system.*** ***Revise a simulation of a system.***	Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS.PS3B.b) ***Energy cannot be created or destroyed.*** ***Energy can be transferred from one object to another and can be transformed from one form to another.*** ***The processes of energy transformation and energy transfer can be used to understand the changes that take place in physical systems.*** Mathematical expressions allow the concept of conservation of energy to be used to predict and describe system behavior. These expressions quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and velocity. (HS.PS3B.c) ***The amount of energy available in a system is mathematically calculable.*** ***Mathematical expressions quantify forms of energy in a system.*** ***These forms can be grouped into types of energy that are associated with the motion of mass (kinetic energy), and types of energy associated with the position of mass and energy fields (potential energy).*** The availability of energy limits what can occur in any system. (HS.PC3B.d) ***The amount of energy available in a system determines what the system is capable of doing.***	

Clarification Statement	
Physical Science	Emphasis is on explaining the meaning of mathematical expressions used in the model. Focus is on basic algebraic expression or computations, systems of two or three components, and thermal energy.
Chemistry	Emphasis is on explaining the meaning of mathematical expressions used in the model. Focus is on basic algebraic expression or computations; systems of

Clarification Statement	
	two or three components; and thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.

Performance Expectation ***and Louisiana Connectors***
HS-PS3-2 Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects). ***LC-HS-PS3-2a Identify that two factors, an object's mass and height above the ground, affect gravitational potential energy (i.e., energy stored due to position of an object above Earth) at the macroscopic level.*** ***LC-HS-PS3-2b Identify that the mass of an object and its speed determine the amount of kinetic energy the object possesses.***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Developing and using models: Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • 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. ***Develop or use a model to identify and describe the components of a system.*** ***Develop or use a model to identify and describe the relationships between the components of a system.*** ***Develop or use a model to predict relationships between systems or within a system.*** ***Identify that models can help***	**DEFINITIONS OF ENERGY** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. There is a single quantity called energy. 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. (HS.PS3A.a) ***Energy is the ability to do work or cause change.*** ***Energy transforms from one form to another, but these transformations are not always reversible.*** ***A system's total energy is conserved regardless of the transfers within the system.*** ***The total energy of a system changes only by the amount of energy transferred into and out of the system.*** At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS.PS3A.b) ***Energy takes many forms; forms may include motion, sound, light, and thermal energy.*** These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as 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.PS3A.c)	**ENERGY AND MATTER** Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. ***Energy cannot be created or destroyed.*** ***Energy can be transferred from one object to another and can be transformed from one form to another, but the total amount of energy never changes.***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
illustrate relationships between systems or within a system.	*Energy can be modeled as either motions of particles or as stored in force fields (electric, magnetic, gravitational).* *At the microscopic scale, energy can be understood as a force that mediates interactions between particles.* *Electromagnetic radiation is a phenomenon in which energy stored in fields moves across space (light, radio waves) with no supporting matter medium.*	

Clarification Statement	
Physical Science	Emphasis is on designing and conducting investigations including evaluating simple series and parallel circuits. Qualitative evidence is used to explain the relationship between a current-carrying wire and a magnetic compass.
Chemistry	Evidence of changes within a circuit can be represented numerically, graphically, or algebraically using Ohm's law. Emphasis is on designing and conducting investigations using qualitative evidence to determine the relationship between electric current and magnetic fields. Examples of evidence can include movement of a magnetic compass needle when placed in the vicinity of a current-carrying wire, and a magnet passing through a coil that turns on the light of a Faraday flashlight.

Performance Expectation *and Louisiana Connectors*
HS-PS3-3 Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. ***LC-HS-PS3-3a Identify the forms of energy that will be converted by a device that converts one form of energy into another form of energy.*** ***LC-HS-PS3-3b Identify steps in a model of a device showing the transformations of energy that occur (e.g., solar cells, solar ovens, generators, turbines).*** ***LC-HS-PS3-3c Describe constraints to the design of the device which converts one form of energy into another form of energy (e.g., cost or efficiency of energy conversion).***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Constructing explanations and designing solutions: Constructing explanations (science) and designing solutions (engineering) in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. ***Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.*** ***Evaluate a solution to a complex***	**DEFINITIONS OF ENERGY** At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS.PS3A.b) ***Energy takes many forms; forms may include motion, sound, light, and thermal energy.*** **ENERGY IN CHEMICAL PROCESSES** Although energy cannot be destroyed, it can be converted to other forms—for example, to thermal energy in the surrounding environment. (HS.PS3D.a) ***A system does not destroy energy when carrying out any process.*** ***When carrying out a process, most often some or all of the energy has been transferred to heat the surrounding environment.*** ***Energy can be transformed into other energy forms.*** ***To produce energy typically means to convert some stored energy into a desired form.*** **DEFINING AND DELIMITING ENGINEERING PROBLEMS** Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS.ETS1A.a) ***A first step in designing a device to solve a problem is prioritizing criteria and constraints for the design of the device.***	**ENERGY AND MATTER** 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. ***The processes of energy transformation and energy transfer can be used to understand the changes that take place in physical systems.***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. *Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.*	*The social, economic, and political forces of a society have a significant influence on what science and technology solutions are implemented.*	

Clarification Statement	
Physical Science	Emphasis is on qualitative evaluations of devices. Constraints could include use of renewable energy forms and efficiency. Emphasis is on devices constructed with teacher approved materials. Examples of devices can be drawn from chemistry or physics clarification statements below.
Chemistry	Emphasis is on both qualitative and quantitative evaluations of devices. Constraints could include use of renewable energy forms and efficiency. Focus of quantitative evaluations is limited to total output for a given input. Emphasis is on devices constructed with teacher approved materials. Examples of devices in chemistry could include hot/cold packs and batteries.
Physics	Emphasis is on both qualitative and quantitative evaluations of devices. Constraints could include use of renewable energy forms and efficiency. Focus of quantitative evaluations is limited to total output for a given input. Emphasis is on devices constructed with teacher approved materials. Examples of devices in physics could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and electric motors.

Performance Expectation ***and Louisiana Connectors***
HS-PS3-4 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 (second law of thermodynamics). ***LC-HS-PS3-4a Identify the temperatures of two liquids of different temperature before mixing and after combining to show uniform energy distribution.*** ***LC-HS-PS3-4b Investigate the transfer of thermal energy when two substances are combined within a closed system.***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Planning and carrying out investigations: Planning and carrying out investigations to answer questions (science) or test solutions to problems (engineering) in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • 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. ***Plan an investigation individually and collaboratively to produce data to serve as the basis for evidence,***	**CONSERVATION OF ENERGY AND ENERGY TRANSFER** Energy cannot be created or destroyed, but it can be transported from one place to another, transformed into other forms, and transferred between systems. (HS.PS3B.b) ***Energy cannot be created or destroyed.*** ***Energy can be transferred from one object to another and can be transformed from one form to another.*** ***The processes of energy transformation and energy transfer can be used to understand the changes that take place in physical systems.*** Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (HS.PS3B.e) ***Energy can change from one kind to another.*** ***When two substances (e.g., water or air) of different temperature are combined (within a closed system), the result will be a more uniform temperature (energy) distribution in the system.*** **ENERGY IN CHEMICAL PROCESSES AND EVERYDAY LIFE** Although energy cannot be destroyed, it can be converted to less useful other forms—for example, to thermal energy in the surrounding environment. (HS.PS3D.a) ***Energy can be transformed into other energy forms.***	**SYSTEMS AND SYSTEM MODELS** When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. ***Making models helps people understand things they cannot observe directly.*** ***Scientists use models to represent things that are either very large or very small.*** ***Any model of a system incorporates assumptions and approximations (e.g., the boundaries and initial conditions of the system, inputs and***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements. *Revise an investigation individually and collaboratively to produce data to serve as the basis for evidence.* *Conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence.*	*When "producing" or "using" energy, most often some or all of the energy has been transferred to heat the surrounding environment.*	*outputs).* *It is critical to be aware of a system's physical, chemical, biological, and social interactions and how they affect the model's reliability and precision.*

Clarification Statement	
Physical Science, Chemistry, and Physics	Emphasis is on analyzing data from student investigations and using mathematical thinking appropriate to the subject to describe the energy changes quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.

Performance Expectation *and Louisiana Connectors*
HS-PS3-5 Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. ***LC-HS-PS3-5a Use a model to identify the cause and effect relationships between forces produced by electric or magnetic fields and the change of energy of the objects in the system.***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Developing and using models: Modeling in 9-12 builds on K-8 experiences and progresses to using synthesizing and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • 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. ***Develop or use a model to identify and describe the components of a system.*** ***Develop or use a model to identify and describe the relationships between the components of a system.*** ***Develop or use a model to predict relationships between systems or within a system.*** ***Identify that models can help***	**RELATIONSHIP BETWEEN ENERGY AND FORCES** When two objects interacting through a field change relative position, the energy stored in the field is changed. (HS.PS3C.a) ***When two objects interact, each one exerts a force on the other.*** ***These forces can transfer energy between the objects.*** ***Forces between two objects at a distance are explained by force fields (gravitational, electric, or magnetic) between them.*** ***The energy stored in the field is consistent with the change in energy of the objects.***	**CAUSE AND EFFECT** Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller scale mechanisms within the system. ***An understanding of small scale mechanisms within a system can uncover cause and effect relationships for complex systems (natural and human-designed).*** ***An understanding of small scale mechanisms within a system can be predictive of cause and effect relationships for complex systems***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
illustrate relationships between systems or within a system.		***(natural and human-designed).***

Clarification Statement	
Physical Science	Examples of models could include drawings, diagrams, simulations and texts, such as what happens when two charged objects or two magnetic poles are near each other.
Physics	Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.

Performance Expectation *and Louisiana Connectors*
HS-PS4-1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. ***LC-HS-PS4-1a Qualitatively describe cause and effect relationships between changes in wave speed and type of media through which the wave travels using mathematical and graphical representations.*** ***LC-HS-PS4-1b Identify examples that illustrate the relationship between the frequency and wavelength of a wave.*** ***LC-HS-PS4-1c Identify evidence that the speed of a wave depends on the media through which it travels.***

Science and Engineering Practice	**Disciplinary Core Idea**	**Crosscutting Concept**
Using mathematics and computational thinking: Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions (e.g., trigonometric, exponential and logarithmic) and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. ***Use mathematical or algorithmic forms for scientific modeling of phenomena to describe claims.***	**WAVE PROPERTIES** The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (HS.PS4A.a) ***The speed of a wave in a particular medium is constant. For this wave, the frequency and the wavelength are related to one another.*** ***The speed of a wave can also be affected by the type of material through which it travels.***	**CAUSE AND EFFECT** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. ***Evidence is required when attributing an observed phenomenon to a specific cause.*** ***Evidence is required to explain the causal mechanisms in a system under study.*** ***Evidence is required to support a claim about the causal mechanisms in a system under study.***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Use mathematical or algorithmic forms for scientific modeling of design solutions to describe claims. *Use mathematical or algorithmic forms for scientific modeling of phenomena to support claims.* *Use mathematical or algorithmic forms for scientific modeling of design solutions to support claims.* *Use mathematical or algorithmic forms for scientific modeling of phenomena to describe explanations.* *Use mathematical or algorithmic forms for scientific modeling of design solutions to describe explanations.* *Use mathematical or algorithmic forms for scientific modeling of phenomena to support explanations.* *Use mathematical or algorithmic forms for scientific modeling of design solutions to support explanations.*		

Clarification Statement	
Physical Science	Emphasis is on describing waves both qualitatively and quantitatively. Qualitative focus includes standard repeating waves and transmission/absorption of electromagnetic waves/radiation.
Physics	Examples of data could include electromagnetic radiation traveling through a vacuum and glass, sound waves traveling through air and water, and seismic

Clarification Statement	
	waves traveling through the Earth. Emphasis is on algebraic relationships and describing those relationships qualitatively.

Performance Expectation *and Louisiana Connectors*
HS-PS4-3 Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. ***LC-HS-PS4-3a Identify a model or description of electromagnetic radiation as a wave model.*** ***LC-HS-PS4-3b Identify a model or description of electromagnetic radiation as a particle model.***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Engaging in argument from evidence: Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. ***Evaluate the claims behind currently accepted explanations to determine the merits of arguments.*** ***Evaluate the claims behind currently accepted solutions to determine the merits of arguments.*** ***Evaluate the evidence behind currently accepted explanations to determine the merits of arguments.*** ***Evaluate the evidence behind***	**WAVE PROPERTIES** Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (HS.PS4A.b) ***Interference is when two waves interact.*** ***Standing waves are formed by the interference of two waves moving in the opposite direction through the same medium.*** ***Interfering waves emerge unaffected by each other.*** **ELECTROMAGNETIC RADIATION** Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS.PS4B.a) ***Energy from the sun takes the form of electromagnetic waves such as infrared, visible, and ultraviolet electromagnetic waves.*** ***Electromagnetic waves carry a single form of energy called electromagnetic (radiant) energy.*** ***The radiation from the sun consists of a range of energies in the electromagnetic spectrum.*** ***Electromagnetic radiation when absorbed can be converted to thermal energy.*** ***Electromagnetic waves carry energy that can have important consequences when transferred to objects or substances.*** ***Some electromagnetic radiation can cause damage to living cells.***	**SYSTEMS AND SYSTEM MODELS** Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. ***Models can be used to simulate systems.*** ***Models can be used to simulate interactions.*** ***Models can be used simulate interactions within systems at different scales.*** ***Models can be used simulate interactions***

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
currently accepted solutions to determine the merits of arguments. Evaluate the reasoning behind currently accepted explanations to determine the merits of arguments. Evaluate the reasoning behind currently accepted solutions to determine the merits of arguments.		***between systems at different scales.***

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. Quantum theory is not included.