Prepared Graduates:

1. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding structure, properties and interactions of matter.

Grade Level Expectation:

1. The sub-atomic structural model and interactions between electric charges at the atomic scale can be used to explain the structure and interactions of matter.

Evidence Outcomes

Students Can:

a. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy levels of atoms. (HS-PS1-1)*(Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.) (Boundary Statement: Limited to main group elements. Does not include quantitative understanding of ionization energy beyond relative trends.)*
b. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. (HS-PS1-3)*(Clarification Statement: Emphasis is on understanding the difference intermolecular versus intramolecular forces and the strengths of forces between particles but not naming specific intermolecular forces, such as dipole-dipole. Examples of particles could include ions, atoms, molecules, and networked materials, such as graphite. Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.) (Boundary Statement: Does not include Raoult's law calculations of vapor pressure or the names, shapes, or bond angles associated with VSEPR theory.)*
c. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. (HS-PS1-4) *(Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.) (Boundary Statement: Does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Use a model to predict the relationships between systems or between components of a system. (Developing and Using Models) (Personal: Initiative/Self-direction)
2. 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 (Planning and Carrying Out Investigations) (Personal: Personal responsibility)

Elaboration on the GLE:

1. Students can answer the question: How do particles combine to form the variety of matter one observes?
2. PS1:A Structure and Properties of Matter: Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.

Cross Cutting Concepts:

1. 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.

Prepared Graduates:

1. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding structure, properties and interactions of matter.

Grade Level Expectation:

2. Chemical processes, their rates, their outcomes, and whether or not energy is stored or released can be understood in terms of collisions of molecules, rearrangement of atoms, and changes in energy as determined by properties of elements involved.

Evidence Outcomes

Students Can:

a. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. (HS-PS1-2) *(Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.) (Boundary Statement: Limited to chemical reactions involving main group elements and combustion reactions).*
b. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. (HS-PS1-4) *(Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.) (Boundary Statement: Does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.)*
c. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. (HS-PS1-5) *(Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.) (Boundary Statement: Limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.)*
d. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium. (HS-PS1-6) *(Clarification Statement: Emphasis is on the application of Le Chatlier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.) (Boundary Statement: Limited to specifying the change in only one variable at a time. Does not include calculating equilibrium constants and concentrations.)*
e. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. (HS-PS1-7) *(Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.) (Boundary Statement: Does not include complex chemical reactions or calculations involving limiting and excess reactants.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations. (Constructing Explanations and Designing Solutions) (Civic/Interpersonal: Civic Engagement)
2. Develop a model based on evidence to illustrate the relationships between systems or between components of a system (Developing and Using Models) (Personal: Personal responsibility)
3. Use mathematical representations of phenomena to support claims (Using Mathematics and Computational Thinking) (Entrepreneurial: Critical thinking/Problem solving)

Elaboration on the GLE:

1. Students can answer the questions: How do substances combine or change (react) to make new substances? How does one characterize and explain these reactions and make predictions about them?
2. PS1:B Chemical Reactions: Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

Cross Cutting Concepts:

1. 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.
2. 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.
3. Stability and Change: Much of science deals with constructing explanations of how things change and how they remain stable.
4. Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems. Science assumes the universe is a vast single system in which basic laws are consistent.

Prepared Graduates:

1. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding structure, properties and interactions of matter.

Grade Level Expectation:

3. The strong nuclear interaction provides the primary force that holds nuclei together. Nuclear processes including fusion, fission, and radioactive decays of unstable nuclei involve changes in nuclear binding energies.

Evidence Outcomes

Students Can:

a. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. (HS-PS1-8) *(Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams and on the scale of energy released in nuclear processes relative to other kinds of transformations. Quantitative models for radioactive decay should not require mathematical manipulations of an exponential equation.) (Boundary Statement: Does not include quantitative calculation of energy released. Limited to alpha, beta, and gamma radioactive decays.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (Developing and Using Models) (Personal: Initiative/Self-direction)

Elaboration on the GLE:

1. Students can answer the question: What forces hold nuclei together and mediate nuclear processes?
2. PS1:C Nuclear Processes: Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.

Cross Cutting Concepts:

1. Energy and Matter: In nuclear processes, atoms are not conserved, but the total number of neutrons plus protons is conserved.

Prepared Graduates:

2. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding interactions between objects and within systems of objects.

Grade Level Expectation:

4. Newton's second law and the conservation of momentum can be used to predict changes in the motion of macroscopic objects.

Evidence Outcomes

Students Can:

a. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. (HS-PS2-1) *(Clarification Statement: 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.). (Boundary Statement: Limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.)*
b. 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. (HS-PS2-2) *(Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.) (Boundary Statement: Limited to systems of two macroscopic bodies moving in one dimension.)*
c. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. (HS-PS2-3) *(Clarification Statement: 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. Examples of a device could include a football helmet or a parachute.) (Boundary Statement: Limited to qualitative evaluations and/or algebraic manipulations.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. 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. (Analyzing and Interpreting Data) (Entrepreneurial: Critical thinking/Problem solving)
2. Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (Constructing Explanations and Designing Solution) (Personal: Personal responsibility)
3. Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems. Science assumes the universe is a vast single system in which basic laws are consistent.
4. Connections to Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena. Theories and laws provide explanations in science. Laws are statements or descriptions of the relationships among observable phenomena.

Elaboration on the GLE:

1. Students can answer the question: How can one predict an object's continued motion, changes in motion, or stability?
2. PS2:A Forces and Motion: Newton's second law accurately predicts changes in the motion of macroscopic objects. Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. 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.

Cross Cutting Concepts:

1. Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Systems can be designed to cause a desired effect.
2. Systems and System Models: When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.

COLORADO Department of Education

Prepared Graduates:

2. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding interactions between objects and within systems of objects.

Grade Level Expectation:

5. Forces at a distance are explained by fields that can transfer energy and can be described in terms of the arrangement and properties of the interacting objects and the distance between them.

Evidence Outcomes

Students Can:

a. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. (HS-PS2-4) *(Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.) (Boundary Statement: Limited to systems with two objects and basic algebraic substitution and/or manipulations.)*

b. 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. (HS-PS2-5) *(Boundary Statement: Limited to designing and conducting investigations with provided materials and tools.)*

c. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials. (HS-PS2-6) *(Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.) (Boundary Statement: Limited to provided molecular structures of specific designed materials.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. 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 and Carry Out an Investigation) (Entrepreneurial: Inquiry/Analysis)
2. Use mathematical representations of phenomena to describe explanations. (Using Mathematics and Computational Thinking) (Entrepreneurial: Critical thinking/Problem solving)
3. Communicate scientific and technical information (e.g., about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (Obtaining, Evaluating, and Communicating Information) (Professional: Information and Communications Technologies)
4. Connections to Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena. Theories and laws provide explanations in science. Laws are statements or descriptions of the relationships among observable phenomena.

Elaboration on the GLE:

1. Students can answer the question: What underlying forces explain the variety of interactions observed?
2. PS2:B 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 distant objects. 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. Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.

Cross Cutting Concepts:

1. 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.
2. Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
3. Structure and Function: Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

COLORADO Department of Education

Prepared Graduates:

3. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how energy is transferred and conserved.

Grade Level Expectation:

6. Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system.

Evidence Outcomes

Students Can:

a. 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. (HS-PS3-1) *(Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.) (Boundary Statement: Limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.)*
b. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects). (HS-PS3-2) *(Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the Earth, and the energy stored between two electrically charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.)*
c. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. (HS-PS3-3) *(Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices and on the ability of energy to be transferred but not on the efficiency of energy transfer. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.) (Boundary Statement: Quantitative evaluations are limited to total output for a given input, and are limited to devices constructed with materials provided to students.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (Developing and Using Models) (Personal: Personal responsibility)
2. Create a computational model or simulation of a phenomenon, designed device, process, or system. (Using Mathematics and Computational Thinking) (Entrepreneurial: Critical thinking/Problem solving)

Elaboration on the GLE:

1. Students can answer the question: What is energy?
2. PS3: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. At the macroscopic scale, energy manifests itself in multiple ways, such as in 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.

Cross Cutting Concepts:

1. System 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.
2. Constructing Explanations and Designing Solutions: Design, evaluate, and/or refine a solution to complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.
3. 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. Energy cannot be created or destroyed — only moves between one place and another place, between objects and/or fields, or between systems.
4. Connections to Engineering, Technology, and Applications of Science: Influence of Science, Engineering, and Technology on Society and the Natural World. Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.
5. Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems. Science assumes the universe is a vast single system in which basic laws are consistent.

Prepared Graduates:

3. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how energy is transferred and conserved.

Grade Level Expectation:

7. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.

Evidence Outcomes

Students Can:

a. 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. (HS-PS3-1) *(Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.) (Boundary Statement: Limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.)*

b. 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). (HS-PS3-4) *(Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.) (Boundary Statement: Limited to investigations based on materials and tools provided to students.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Create a computational model or simulation of a phenomenon, designed device, process, or system. (Using Mathematics and Computational Thinking) (Entrepreneurial: Critical thinking/Problem solving)
2. 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. (Planning and Carrying Out Investigations) (Entrepreneurial: Inquiry/Analysis)

Elaboration on the GLE:

1. Students can answer the questions: What is meant by conservation of energy? How is energy transferred between objects or systems?

2. PS3:B 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. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Mathematical expressions, which 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 speed, allow the concept of conservation of energy to be used to predict and describe system behavior. The availability of energy limits what can occur in any system. 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).

Cross Cutting Concepts:

1. Systems and Systems 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. 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.
2. Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems. Science assumes the universe is a vast single system in which basic laws are consistent.

Prepared Graduates:

3. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how energy is transferred and conserved.

Grade Level Expectation:

8. Force fields (gravitational, electric, and magnetic) contain energy and can transmit energy across space from one object to another.

Evidence Outcomes

Students Can:

a. 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. (HS-PS3-5) *(Clarification Statement: 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.) (Boundary Statement: Limited to systems containing two objects.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (Developing and Using Models) (Personal: Initiative/Self direction)

Elaboration on the GLE:

1. Students can answer the question: How are forces related to energy?
2. PS3:C Relationship Between Energy and Forces: When two objects interacting through a field change relative position, the energy stored in the field is changed.

Cross Cutting Concepts:

1. 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.

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Prepared Graduates:

3. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how energy is transferred and conserved.

Grade Level Expectation:

9. Although energy cannot be destroyed, it can be converted to less useful forms as it is captured, stored and transferred.

Evidence Outcomes

Students Can:

a. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. (HS-PS3-3) *(Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices, including the identification of different energy types [starting points] and how they are transferred. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.) (Boundary Statement: Quantitative evaluation is limited to total output for a given input. Limited to devices constructed with materials provided to students.)*
b. 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). (HS-PS3-4) *(Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.) (Boundary Statement: Limited to investigations based on materials and tools provided to students.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Design, evaluate, and/or refine a solution to complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations. (Constructing Explanations and Designing Solutions) (Civic/Interpersonal: Civic engagement)
2. 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. (Planning on Carrying Out Investigations) (Personal: Initiative/Self-direction)

Elaboration on the GLE:

1. Students can answer the questions: How do food and fuel provide energy? If energy is conserved, why do people say it is produced or used?
2. PS3:D Energy in Chemical Processes and Everyday Life: Although energy cannot be destroyed, it can be converted to less useful forms — for example, to thermal energy in the surrounding environment.

Cross Cutting Concepts:

1. 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.
2. Systems and Systems 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.

Prepared Graduates:

4. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how waves are used to transfer energy and information.

Grade Level Expectation:

10. Waves have characteristic properties and behaviors.

Evidence Outcomes

Students Can:

a. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. (HS-PS4-1) *(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.) (Boundary Statement: Limited to algebraic relationships and describing those relationships qualitatively.)*

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

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. (Asking Questions and Defining Problems) (Entrepreneurial: Inquiry/Analysis)
2. Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (Using Mathematics and Computational Thinking) (Entrepreneurial: Critical thinking/Problem solving)
3. Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (Engaging in Argument from Evidence) (Personal: Initiative/Self-direction)
4. Connections to Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena. A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.

Elaboration on the GLE:

1. Students can answer the question: What are the characteristic properties and behaviors of waves?
2. PS4:A 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. Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary Statement: 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.)

Cross Cutting Concepts:

1. 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.
2. Systems and Systems 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.

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Prepared Graduates:

4. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how waves are used to transfer energy and information.

Grade Level Expectation:

11. Both an electromagnetic wave model and a photon model explain features of electromagnetic radiation broadly and describe common applications of electromagnetic radiation.

Evidence Outcomes

Students Can:

a. 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. (HS-PS4-3) *(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.) (Boundary Statement: Does not include using quantum theory.)*
b. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. (HS-PS4-4) *(Clarification Statement: Emphasis is on the idea that different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Some examples may include: sunscreen SPF, lasers stimulating particular material to resonate at a particular frequency, and a discussion of how color is perceived as it relates to frequency. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.)*
c. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. (HS-PS4-5) *(Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.) (Boundary Statement: Limited to qualitative information and does not include band theory.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (Engaging in Argument from Evidence) (Personal: Initiative/Self-direction)
2. Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. Communicate technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally , graphically , textually , and mathematically). (Obtaining, Evaluating, and Communicating Information) (Entrepreneurial: Inquiry/Analysis)
3. Connections to Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena. A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.

Elaboration on the GLE:

1. Students can answer the questions: What is light? How can one explain the varied effects that involve light? What other forms of electromagnetic radiation are there?
2. PS4:B Electromagnetic Radiation: Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. 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-ray s, gamma rays) can ionize atoms and cause damage to living cells. Photoelectric materials emit electrons when they absorb light of a high-enough frequency.

Cross Cutting Concepts:

1. 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. Systems can be designed to cause a desired effect.
2. 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.
3. Connections to Engineering, Technology, and Applications of Science: Interdependence of Science, Engineering, and Technology. Science and engineering complement each other in the cycle known as research and development (R&D).
4. Influence of Engineering, Technology, and Science on Society and the Natural World: Modern civilization depends on major technological systems.

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Prepared Graduates:

4. Students can use the full range of science and engineering practices to make sense of natural phenomena and solve problems that require understanding how waves are used to transfer energy and information.

Grade Level Expectation:

12. Multiple technologies that are part of everyday experiences are based on waves and their interactions with matter.

Evidence Outcomes

Students Can:

a. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. (HS-PS4-5) *(Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.) (Boundary Statement: Limited to qualitative information. Does not include band theory.)*

Academic Context and Connections

Colorado Essential Skills and Science and Engineering Practices:

1. Communicate technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (Obtaining, Evaluating, and Communicating Information) (Professional: Information literacy)
2. Influence of Engineering, Technology, and Science on Society and the Natural World: Modern civilization depends on major technological systems.

Elaboration on the GLE:

1. Students can answer the question: How are instruments that transmit and detect waves used to extend human senses?
2. 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.

Cross Cutting Concepts:

1. Cause and Effect: Systems can be designed to cause a desired effect.
2. Connections to Engineering, Technology, and Applications of Science: Interdependence of Science, Engineering, and Technology: Science and engineering complement each other in the cycle known as research and development (R&D).