Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.

Key Idea 4:

Energy exists in many forms, and when these forms change energy is conserved.

The law of conservation of energy provides one of the basic keys to understanding the universe. The fundamental tenet of this law is that the total mass-energy of the universe is constant; however, energy can be transferred in many ways. Historically, scientists have treated the law of conservation of matter and energy separately. All energy can be classified as either kinetic or potential. When work is done on or by a system, the energy of the system changes. This relationship is known as the work-energy theorem.

Energy may be transferred by matter or by waves. Waves transfer energy without transferring mass. Most of the information scientists gather about the universe is derived by detecting and analyzing waves. This process has been enhanced through the use of digital analysis. Types of waves include mechanical and electromagnetic. All waves have the same characteristics and exhibit certain behaviors, subject to the constraints of conservation of energy.

Note: the use of e.g. *denotes examples which may be used for in-depth study. The terms* for example *and* such as *denote material which is testable. Items in parantheses denote further definition of the word(s) preceding the item and are testable.*

PERFORMANCE INDICATOR 4.1

Students can observe and describe transmission of various forms of energy.

Major Understandings:

4.1a All energy transfers are governed by the law of conservation of energy.*

4.1b Energy may be converted among mechanical, electromagnetic, nuclear, and thermal forms.

4.1c Potential energy is the energy an object possesses by virtue of its position or condition. Types of potential energy include gravitational* and elastic*.

4.1d Kinetic energy* is the energy an object possesses by virtue of its motion.

4.1e In an ideal mechanical system, the sum of the macroscopic kinetic and potential energies (mechanical energy) is constant.*

4.1f In a nonideal mechanical system, as mechanical energy decreases there is a corresponding increase in other energies such as internal energy.*

4.1g When work* is done on or by a system, there is a change in the total energy* of the system.

4.1h Work done against friction results in an increase in the internal energy of the system.

4.1i Power* is the time-rate at which work is done or energy is expended.

(Note: Items with asterisks* require quantitative treatment per the Reference Table for Physics. Asterisks following individual words refer to the preceding word or phrase only; asterisks appearing after the final period of a sentence refer to all concepts or ideas presented in the sentence.)

PERFORMANCE INDICATOR 4.1

continued

4.1j Energy may be stored in electric* or magnetic fields. This energy may be transferred through conductors or space and may be converted to other forms of energy.

4.1k Moving electric charges produce magnetic fields. The relative motion between a conductor and a magnetic field may produce a potential difference in the conductor.

4.1l All materials display a range of conductivity. At constant temperature, common metallic conductors obey Ohm's Law*.

4.1m The factors affecting resistance in a conductor are length, cross-sectional area, temperature, and resistivity.*

4.1n A circuit is a closed path in which a current* can exist. (*Note: Use conventional current.*)

4.1o Circuit components may be connected in series* or in parallel*. Schematic diagrams are used to represent circuits and circuit elements.

4.1p Electrical power* and energy* can be determined for electric circuits.

PERFORMANCE INDICATOR 4.3

Students can explain variations in wavelength and frequency in terms of the source of the vibrations that produce them, e.g., molecules, electrons, and nuclear particles.

Major Understandings:

4.3a An oscillating system produces waves. The nature of the system determines the type of wave produced.

4.3b Waves carry energy and information without transferring mass. This energy may be carried by pulses or periodic waves.

4.3c The model of a wave incorporates the characteristics of amplitude, wavelength,* frequency*, period*, wave speed*, and phase.

4.3d Mechanical waves require a material medium through which to travel.

4.3e Waves are categorized by the direction in which particles in a medium vibrate about an equilibrium position relative to the direction of propagation of the wave, such as transverse and longitudinal waves.

4.3f Resonance occurs when energy is transferred to a system at its natural frequency.

4.3g Electromagnetic radiation exhibits wave characteristics. Electromagnetic waves can propagate through a vacuum.

4.3h When a wave strikes a boundary between two media, reflection*, transmission, and absorption occur. A transmitted wave may be refracted.

4.3i When a wave moves from one medium into another, the wave may refract due to a change in speed. The angle of refraction (measured with respect to the normal) depends on the angle of incidence and the properties of the media (indices of refraction).*

4.3j The absolute index of refraction is inversely proportional to the speed of a wave.*

PERFORMANCE INDICATOR 4.3

continued

4.3k All frequencies of electromagnetic radiation travel at the same speed in a vacuum.*

4.3l Diffraction occurs when waves pass by obstacles or through openings. The wavelength of the incident wave and the size of the obstacle or opening affect how the wave spreads out.

4.3m When waves of a similar nature meet, the resulting interference may be explained using the principle of superposition. Standing waves are a special case of interference.

4.3n When a wave source and an observer are in relative motion, the observed frequency of the waves traveling between them is shifted (Doppler effect).

Key Idea 5:

Energy and matter interact through forces that result in changes in motion.

Introduction: Fundamental forces govern all the interactions of the universe. The interaction of masses is determined by the gravitational force; the interaction of charges is determined by the electro-weak force; the interaction between particles in the nucleus is controlled by the strong force. Changes in the motion of an object require a force. Newton's laws can be used to explain and predict the motion of an object.

On the atomic level, the quantum nature of the fundamental forces becomes evident. Models of the atom have been developed to incorporate wave-particle duality, quantization, and the conservation laws. These models have been modified to reflect new observations; they continue to evolve.

Everyday experiences are manifestations of patterns that repeat themselves from the subnuclear to the cosmic level. Models that are used at each level reflect these patterns. The future development of physics is likely to be derived from these realms.

PERFORMANCE INDICATOR 5.1

Students can explain and predict different patterns of motion of objects (e.g., linear and uniform circular motion, velocity and acceleration, momentum and inertia).

Major Understandings:

5.1a Measured quantities can be classified as either vector or scalar.

5.1b A vector may be resolved into perpendicular components.*

5.1c The resultant of two or more vectors, acting at any angle, is determined by vector addition.

5.1d An object in linear motion may travel with a constant velocity* or with acceleration*. *(Note: Testing of acceleration will be limited to cases in which acceleration is constant.)*

5.1e An object in free fall accelerates due to the force of gravity.* Friction and other forces cause the actual motion of a falling object to deviate from its theoretical motion. *(Note: Initial velocities of objects in free fall may be in any direction.)*

5.1f The path of a projectile is the result of the simultaneous effect of the horizontal and vertical components of its motion; these components act independently.

5.1g A projectile's time of flight is dependent upon the vertical component of its motion.

PERFORMANCE INDICATOR 5.1

continued

5.1h The horizontal displacement of a projectile is dependent upon the horizontal component of its motion and its time of flight.

5.1i According to Newton's First Law, the inertia of an object is directly proportional to its mass. An object remains at rest or moves with constant velocity, unless acted upon by an unbalanced force.

5.1j When the net force on a system is zero, the system is in equilibrium.

5.1k According to Newton's Second Law, an unbalanced force causes a mass to accelerate*.

5.1l Weight is the gravitational force with which a planet attracts a mass*. The mass of an object is independent of the gravitational field in which it is located.

5.1m The elongation or compression of a spring depends upon the nature of the spring (its spring constant) and the magnitude of the applied force.*

5.1n Centripetal force* is the net force which produces centripetal acceleration.* In uniform circular motion, the centripetal force is perpendicular to the tangential velocity.

5.1o Kinetic friction* is a force that opposes motion.

5.1p The impulse* imparted to an object causes a change in its momentum*.

5.1q According to Newton's Third Law, forces occur in action/reaction pairs. When one object exerts a force on a second, the second exerts a force on the first that is equal in magnitude and opposite in direction.

5.1r Momentum is conserved in a closed system.* *(Note: Testing will be limited to momentum in one dimension.)*

5.1s Field strength* and direction are determined using a suitable test particle. *(Notes: 1)Calculations are limited to electrostatic and gravitational fields. 2)The gravitational field near the surface of Earth and the electrical field between two oppositely charged parallel plates are treated as uniform.)*

5.1t Gravitational forces are only attractive, whereas electrical and magnetic forces can be attractive or repulsive.

5.1u The inverse square law applies to electrical* and gravitational* fields produced by point sources.

PERFORMANCE INDICATOR 5.3

Students can compare energy relationships within an atom's nucleus to those outside the nucleus.

Major Understandings:

5.3a States of matter and energy are restricted to discrete values (quantized).

5.3b Charge is quantized on two levels. On the atomic level, charge is restricted to multiples of the elementary charge (charge on the electron or proton). On the subnuclear level, charge appears as fractional values of the elementary charge (quarks).

5.3c On the atomic level, energy is emitted or absorbed in discrete packets called photons.*

5.3d The energy of a photon is proportional to its frequency.*

5.3e On the atomic level, energy and matter exhibit the characteristics of both waves and particles.

5.3f Among other things, mass-energy and charge are conserved at all levels (from subnuclear to cosmic).

5.3g The Standard Model of Particle Physics has evolved from previous attempts to explain the nature of the atom and states that:

- atomic particles are composed of subnuclear particles
- the nucleus is a comglomeration of quarks which manifest themselves as protons and neutrons
- each elementary particle has a corresponding antiparticle

5.3h Behaviors and characteristics of matter, from the microscopic to the cosmic levels, are manifestations of its atomic structure. The macroscopic characteristics of matter, such as electrical and optical properties, are the result of microscopic interactions.

5.3i The total of the fundamental interactions is responsible for the appearance and behavior of the objects in the universe.

5.3j The fundamental source of all energy in the universe is the conversion of mass into energy.*