Ohio Science

Physical Science Content Elaborations: Grades 9-12

Adopted 2018

Physical Science

Study Of Matter

1. Classification of matter PS.M.1
    1. Students understand that matter can be classified in broad categories, such as homogeneous and heterogeneous, according to its composition or by its chemical properties (e.g., reactivity, flammability, pH) and physical properties (e.g., color, solubility, odor, hardness, density, conductivity, melting point and boiling point, viscosity, malleability). PS.M.1.1
    2. Students understand that solutions are homogeneous mixtures of a solute dissolved in a solvent. PS.M.1.2
    3. Students understand that the amount of a solid solute that can dissolve in a solvent generally increases as the temperature increases since the particles have more kinetic energy to overcome the attractive forces between them. PS.M.1.3
    4. Students understand that water is often used as a solvent since so many substances will dissolve in water. PS.M.1.4
    5. Students understand that aqueous solutions can be classified as acidic (below 7 on the pH scale), neutral (7 on the pH scale), or basic (above 7 on the pH scale), but the discussion of hydroxide and hydrogen ions as they relate to the pH scale is reserved for Chemistry. PS.M.1.5
    6. Students understand that physical properties can be used to separate the substances in mixtures, including solutions. PS.M.1.6
    7. Students understand that phase changes can be represented by graphing the temperature of a sample vs. the time it has been heated. PS.M.1.7
    8. Students understand that investigations include collecting data during heating, cooling and solid-liquid-gas phase changes. PS.M.1.8
    9. Students understand that at times, the temperature will change steadily, indicating a change in the motion of the particles and the kinetic energy of the substance. However, during a phase change, the temperature of a substance does not change, indicating there is no change in kinetic energy. PS.M.1.9
    10. Students understand that since the substance continues to gain or lose energy during phase changes, these changes in energy are potential and indicate a change in the position of the particles. PS.M.1.10
    11. Students understand that when heating a substance, a phase change will occur when the kinetic energy of the particles is great enough to overcome the attractive forces between the particles; the substance then melts or boils. PS.M.1.11
    12. Students understand that when cooling a substance, a phase change will occur when the kinetic energy of the particles is no longer great enough to overcome the attractive forces between the particles; the substance then condenses or freezes. PS.M.1.12
    13. Students understand that phase changes are examples of changes that can occur when energy is absorbed from the surroundings (endothermic) or released into the surroundings (exothermic). PS.M.1.13

14. Students understand that when thermal energy is added to a solid, liquid or gas, most substances increase in volume because the increased kinetic energy of the particles causes an increased distance between the particles. This results in a change in density of the material. PS.M.1.14
15. Students understand that solids have greater density than liquids, which have greater density than gases due to the spacing between the particles. PS.M.1.15
16. Students understand that the density of a substance can be calculated from the slope of a mass vs. volume graph. PS.M.1.16
17. Students understand that differences in densities can be determined by interpreting mass vs. volume graphs of the substances. PS.M.1.17
18. Students should be able to calculate mass, volume or density, given two of the three values. PS.M.1.18

2. Atoms PS.M.2
    1. Students understand that the atom is composed of protons, neutrons and electrons that have measurable properties, including mass and, in the case of protons and electrons, a characteristic charge. PS.M.2.1
    2. Students understand that an atom is empty space with a very small positively charged nucleus. PS.M.2.2
    3. Students understand that the nucleus is composed of protons and neutrons. PS.M.2.3
    4. Students understand that the electrons move about in the empty space that surrounds the nucleus. PS.M.2.4
    5. Students understand that although current understanding goes beyond the Bohr Model, it can still be used to represent the atom and develop the idea of valence electrons. PS.M.2.5
    6. Students understand that experimental evidence that led to the development of historic atomic models is reserved for Chemistry. PS.M.2.6
    7. Students understand that all atoms of a particular element have the same atomic number; an element may have different isotopes with different mass numbers. PS.M.2.7
    8. Students understand that atoms may gain or lose valence electrons to become anions or cations. PS.M.2.8
    9. Students understand that atomic number, mass number, charge and identity of the element can be determined from the numbers of protons, neutrons and electrons. PS.M.2.9
    10. Students understand that atomic mass calculations and explanations about configuration of electrons and how atomic spectra are produced are reserved for Chemistry. PS.M.2.10

3. Periodic trends of the elements PS.M.3
    1. Students understand that the periodic table was arranged so that elements with similar chemical and physical properties are in the same group or family. PS.M.3.1

2. Students understand that when elements are listed in order of increasing atomic number, the same sequence of properties appears over and over again; this is the periodic law. PS.M.3.2
3. Students understand that trends in simple observable properties, like density or melting point, can be examined within families or groups on the periodic table. These trends allow scientists to make predictions about new elements. PS.M.3.3
4. Students understand that metalloids are elements that have some properties of metals and some properties of nonmetals. PS.M.3.4
5. Students understand that metals, nonmetals, metalloids, periods and groups or families including the alkali metals, alkaline earth metals, halogens and noble gases can be identified by their position on the periodic table. PS.M.3.5
6. Students understand that elements in Groups 1, 2 and 17 have characteristic ionic charges that will be used in this course to predict the formulas of compounds. PS.M.3.6
7. Students understand that other trends in the periodic table (e.g., atomic radius, electronegativity, ionization energies) are reserved for Chemistry. PS.M.3.7

4. Bonding and compounds PS.M.4
   1. Students understand that atoms may be bonded together by losing, gaining or sharing valence electrons to form molecules or three-dimensional lattices. PS.M.4.1
   2. Students understand that an ionic bond involves the attraction of two oppositely charged ions, typically a metal cation and a nonmetal anion formed by transferring electrons between the atoms. PS.M.4.2
   3. Students understand that an ion attracts oppositely charged ions from every direction, resulting in the formation of a three-dimensional lattice. PS.M.4.3
   4. Students understand that covalent bonds result from the sharing of electrons between two atoms, usually nonmetals. PS.M.4.4
   5. Students understand that covalent bonding can result in the formation of structures ranging from small individual molecules to three-dimensional lattices (e.g., diamond). PS.M.4.5
   6. Students understand that the bonds in most compounds fall on a continuum between the two extreme models of bonding: ionic and covalent. PS.M.4.6
   7. Students understand that using the periodic table to determine ionic charge, formulas of ionic compounds containing elements from groups 1, 2, 17, hydrogen and oxygen can be predicted. PS.M.4.7
   8. Students understand that given a chemical formula, a compound can be named using conventional systems that include Greek prefixes where appropriate. PS.M.4.8
   9. Students understand that prefixes will be limited to represent values from one to 10. PS.M.4.9
   10. Students understand that given the name of an ionic or covalent substance, formulas can be written. PS.M.4.10

11. Students understand that prediction of bond types from electronegativity values, polar covalent bonds, and writing formulas/naming compounds that contain polyatomic ions or transition metals are reserved for Chemistry. PS.M.4.11

5. Reactions of matter PS.M.5
    1. Students understand that stoichiometric relationships beyond the coefficients in a balanced equation and classification of types of chemical reactions are reserved for Chemistry. PS.M.5.1
    2. Students understand that during chemical reactions, thermal energy is either transferred from the system to the surroundings (exothermic) or transferred from the surroundings to the system (endothermic). Since the environment surrounding the system can be large, temperature changes in the surroundings may not be detectable. PS.M.5.2
    3. Students understand that nuclear reactions involve changes to the nucleus and typically produce much larger energies than chemical reactions. PS.M.5.3
    4. Students understand that the strong nuclear force is an attractive force that binds protons and neutrons together in the nucleus. PS.M.5.4
    5. Students understand that while the nuclear force is extremely weak at most distances, over the very short distances present in the nucleus the force is greater than the repulsive electrical forces among protons. PS.M.5.5
    6. Students understand that when the attractive nuclear forces and repulsive electrical forces in the nucleus are not balanced, the nucleus is unstable. PS.M.5.6
    7. Students understand that through radioactive decay, the unstable nucleus emits radiation in the form of very fast-moving particles and energy to produce a new nucleus. Nuclei that undergo this process are said to be radioactive. PS.M.5.7
    8. Students understand that radioactive decay can result in the release of different types of radiation (alpha, beta, gamma), each with a characteristic mass, charge, and potential to alter and penetrate the material it strikes. PS.M.5.8
    9. Students understand that alpha decay changes the identity of the element. PS.M.5.9
    10. Students understand that beta decay results from the decay of a neutron. PS.M.5.10
    11. Students understand that when a radioisotope undergoes alpha or beta decay, the resulting nucleus can be predicted and the balanced nuclear equation can be written. PS.M.5.11
    12. Students understand that for any radioisotope, the half-life is unique and predictable. PS.M.5.12
    13. Students understand that graphs can be constructed that show the amount of a radioisotope that remains as a function of time and can be interpreted to determine the value of the half-life. PS.M.5.13
    14. Students understand that half-life values are used in radioactive dating. Only whole number integers of half-lives will be addressed in this course. PS.M.5.14

15. Students understand that other examples of nuclear processes include nuclear fission and nuclear fusion. PS.M.5.15
16. Students understand that nuclear fission involves splitting a large nucleus into smaller nuclei, releasing large quantities of energy. PS.M.5.16
17. Students understand that nuclear fusion is the joining of smaller nuclei into a larger nucleus accompanied by the release of large quantities of energy. PS.M.5.17
18. Students understand that nuclear fusion is the process responsible for formation of elements in the universe beyond hydrogen and is the source of energy in the sun and other stars. PS.M.5.18
19. Students understand that using nuclear reactions as an energy resource can be addressed. PS.M.5.19
20. Students understand that further details about nuclear processes, including mass-energy equivalence and nuclear power applications, are addressed in Physics. PS.M.5.20

Energy And Waves

1. Conservation of energy `PS.EW.1`
    1. Students understand that energy content learned in middle school, specifically conservation of energy and the basic differences between kinetic and potential energy, is elaborated on and quantified in this course. `PS.EW.1.1`
    2. Students understand that energy has no direction and has units of joules (J). `PS.EW.1.2`
    3. Students understand that kinetic energy, E_k, can be mathematically represented by E_k = ½mv^2. `PS.EW.1.3`
    4. Students understand that potential energy, E_g, can be mathematically represented by Eg = mgh. `PS.EW.1.4`
    5. Students understand that the amount of gravitational potential energy of an object is measured relative to a reference that is considered to be at a point of zero energy. The reference may be changed to help understand different situations. `PS.EW.1.5`
    6. Students understand that only the change in the amount of energy can be measured absolutely. `PS.EW.1.6`
    7. Students understand that the conservation of energy and equations for kinetic and gravitational potential energy can be used to calculate values associated with energy (e.g., height, mass, speed) for situations involving energy transfer and transformation. `PS.EW.1.7`
    8. Students understand that opportunities to quantify energy from data collected in experimental situations (e.g., a swinging pendulum, a car traveling down an incline) should be provided. `PS.EW.1.8`
2. Transfer and transformation of energy (including work) `PS.EW.2`
    1. Students understand that as long as the force, F, and displacement, Δx, are in the same or opposite directions, work, W, can be calculated from the equation $W = F\Delta x$. `PS.EW.2.1`
    2. Students understand that work can also be quantified as $W = \Delta E$. `PS.EW.2.2`
    3. Students understand that energy transformations for a phenomenon can be represented through a series of pie graphs or bar graphs. `PS.EW.2.3`
    4. Students understand that equations for work, kinetic energy and potential energy can be combined with the law of conservation of energy to solve problems; conceptual understanding of kinetic energy, potential energy and work should be emphasized. `PS.EW.2.4`
    5. Students understand that when energy is transferred from one system to another, some of the energy is transformed to thermal energy. `PS.EW.2.5`
    6. Students understand that since thermal energy involves the random movement of many trillions of subatomic particles, it is less able to be organized to bring about further change. `PS.EW.2.6`

7. Students understand that therefore, even though the total amount of energy remains constant, less energy is available for doing useful work. PS.EW.2.7

3. Waves PW.EW.3

    1. Students understand that when a wave encounters a new material, the new material may absorb the energy of the wave by transforming it to another form of energy, usually thermal energy. PS.EW.3.1
    2. Students understand that waves can be reflected off solid barriers or refracted when a wave travels from one medium into another medium. PS.EW.3.2
    3. Students understand that waves may undergo diffraction around small obstacles or openings. PS.EW.3.3
    4. Students understand that when two waves traveling through the same medium meet, they pass through each other and continue traveling through the medium as before. When the waves meet, they undergo superposition, demonstrating constructive and destructive interference. PS.EW.3.4
    5. Students understand that sound travels in waves and undergoes reflection, refraction, interference and diffraction. PS.EW.3.5
    6. Students understand that radiant energy travels in waves and does not require a medium. PS.EW.3.6
    7. Students understand that sources of light energy (e.g., the sun, a light bulb) radiate energy continuously in all directions. PS.EW.3.7
    8. Students understand that radiant energy has a wide range of frequencies, wavelengths and energies arranged into the electromagnetic spectrum. PS.EW.3.8
    9. Students understand that the electromagnetic spectrum is divided into bands that have different applications in everyday life: radio (lowest energy), microwaves, infrared, visible light, ultraviolet, X-rays and gamma rays (highest energy). PS.EW.3.9
    10. Students understand that radiant energy of the entire electromagnetic spectrum travels at the same speed in a vacuum. PS.EW.3.10
    11. Students understand that specific frequency, energy, or wavelength ranges of the electromagnetic spectrum are not required. PS.EW.3.11
        a. Students also understand that the relative positions of the different bands, including the colors of visible light, are important (e.g., ultraviolet has more energy than microwaves). PS.EW.3.11.A
        b. Students understand that total radiant energy depends on more than just the frequency. PS.EW.3.11.B
    12. Students understand that radiant energy exhibits wave behaviors including reflection, refraction, absorption, superposition and diffraction. PS.EW.3.12
    13. Students understand that for opaque objects (e.g., paper, a chair, an apple), little if any radiant energy is transmitted into the new material. However, the radiant energy can be absorbed, usually increasing the thermal energy of the object and/or the radiant energy can be reflected. PS.EW.3.13

14. Students understand that for rough objects, the reflection in all directions forms a diffuse reflection and for smooth shiny objects, reflections can result in clear images. PS.EW.3.14
15. Students understand that transparent materials transmit most of the energy through the material, but smaller amounts of energy may be absorbed or reflected. PS.EW.3.15
16. Students understand that changes in the observed frequency and wavelength of a wave can occur if the wave source and the observer are moving relative to each other. PS.EW.3.16
17. Students understand that when the source and the observer are moving toward each other, the wavelength is shorter and the observed frequency is higher; when the source and the observer are moving away from each other, the wavelength is longer and the observed frequency is lower. PS.EW.3.17
    a. Students understand that this phenomenon is called the Doppler shift and can be illustrated by listening to an ambulance siren as it travels past. This phenomenon is important to current understanding of how the universe is expanding. PS.EW.3.17.A
18. Students understand that the light we receive from distant galaxies has a noticeable shift toward redder wavelengths (the so-called "redshift"). PS.EW.3.18

4. Thermal energy PS.EW.4
    1. Students understand that thermal conductivity depends on the rate at which thermal energy is transferred from one end of a material to another. PS.EW.4.1
    2. Students understand that thermal conductors have a high rate of thermal energy transfer and thermal insulators have a slow rate of thermal energy transfer. PS.EW.4.2
    3. Students understand that the rate at which thermal radiation is absorbed or emitted by a system depends on its temperature, color, texture and exposed surface area. PS.EW.4.3
    4. Students understand that all other things being equal, in a given amount of time, black rough surfaces absorb more thermal energy than smooth white surfaces. PS.EW.4.4
    5. Students understand that an object or system is continuously absorbing and emitting thermal radiation. PS.EW.4.5
    6. Students understand that if the object or system absorbs more thermal energy than it emits and there is no change in phase, the temperature increases. PS.EW.4.6
    7. Students understand that if the object or system emits more thermal energy than is absorbed and there is no change in phase, the temperature decreases. PS.EW.4.7
    8. Students understand that for an object or system in thermal equilibrium, the amount of thermal energy absorbed is equal to the amount of thermal energy emitted; therefore, the temperature remains constant. PS.EW.4.8

9. Students understand that in Chemistry, changes in thermal energy will be quantified for substances that change their temperature. PS.EW.4.9

5. Electricity PS.EW.5
    1. Students understand that a complete loop is needed for an electrical circuit that may be in parallel or in series. PS.EW.5.1
    2. Students understand that the differences between electrical conductors and insulators can be explained by how freely the electrons flow throughout the material due to how firmly electrons are held by the nucleus. PS.EW.5.2
    3. Students understand that by convention, electric current is the rate at which positive charge flows in a circuit. PS.EW.5.3
    4. Students understand that it is the negatively charged electrons that are actually moving. PS.EW.5.4
    5. Students understand that current is measured in amperes (A). An ampere is equal to one coulomb of charge per second (C/s). PS.EW.5.5
    6. Students understand that in an electric circuit, the power source supplies the electrons already in the circuit with electric potential energy by doing work to separate opposite charges. PS.EW.5.6
    7. Students understand that for a battery, the energy is provided by a chemical reaction that separates charges on the positive and negative sides of the battery. PS.EW.5.7
        a. Students understand that this separation of charge is what causes the electrons to flow in the circuit. PS.EW.5.7.A
        b. Students understand that these electrons then transfer energy to other objects and transform electrical energy into other forms (e.g., light, sound, heat) in the resistors. PS.EW.5.7.B
    8. Students understand that current continues to flow even after the electrons transfer their energy. Resistors oppose the rate of charge flow in the circuit. PS.EW.5.8
    9. Students understand that the potential difference or voltage across an energy source is a measure of potential energy in joules supplied to each coulomb of charge. PS.EW.5.9
    10. Students understand that the volt (V) is the unit of potential difference and is equal to one joule of energy per coulomb of charge (J/C). PS.EW.5.10
    11. Students understand that potential difference across the circuit is a property of the energy source and does not depend upon the devices in the circuit. These concepts can be used to explain why current will increase as the potential difference increases and as the resistance decreases. PS.EW.5.11
    12. Students understand that experiments, investigations and testing (3-D or virtual) are used to construct a variety of circuits and to measure and compare the potential difference (voltage) and current. PS.EW.5.12

Forces And Motion

1. Motion PS.FM.1

1. Students understand that the motion of an object depends on the observer's frame of reference and is described in terms of distance, position, displacement, speed, velocity, acceleration and time. PS.FM.1.1
2. Students understand that position, displacement, velocity and acceleration are all vector properties (magnitude and direction). PS.FM.1.2
3. Students understand that all motion is relative to whatever frame of reference is chosen for there is no motionless frame from which to judge all motion. PS.FM.1.3
4. Students understand that motion diagrams can be drawn and interpreted to represent the position and velocity of an object. PS.FM.1.4
5. Students understand that the displacement or change in position of an object is a vector quantity that can be calculated by subtracting the initial position from the final position (Δx = x_f – x_i). PS.FM.1.5
6. Students understand that displacement can be positive or negative depending upon the direction of motion. PS.FM.1.6
7. Students understand that displacement is not always equal to the distance travelled. PS.FM.1.7
    a. Understand that examples should be given where the distance is not the same as the displacement. PS.FM.1.7.A
8. Students understand that velocity is a vector quantity that represents the rate at which position changes. PS.FM.1.8
9. Students understand that average velocity can be calculated by dividing displacement (change in position) by the elapsed time (v_{avg} = (x_f – x_i)/(t_f – t_i)). PS.FM.1.9
10. Students understand that velocity may be positive or negative depending upon the direction of motion. PS.FM.1.10
11. Students understand that velocity should be distinguished from speed, which is always positive. PS.FM.1.11
12. Students understand that provide examples of when the average speed is not the same as the average velocity. PS.FM.1.12
13. Students understand that objects that move with constant velocity have the same displacement for each successive time interval. PS.FM.1.13
14. Students understand that while speeding up or slowing down and/or changing direction, the velocity of an object changes continuously, from instant to instant. PS.FM.1.14
15. Students understand that the speed of an object at any instant (clock reading) is called instantaneous speed. PS.FM.1.15
16. Students understand that acceleration is a vector quantity that represents the rate at which velocity changes. PS.FM.1.16
17. Students understand that average acceleration can be calculated by dividing the change in velocity by elapsed time (a_{avg} = (v_f – v_i)/(t_f – t_i)). PS.FM.1.17

18. Students understand that deceleration is an ambiguous term that should only be used when an object is slowing down. PS.FM.1.18
19. Students understand that objects that have no acceleration can either be standing still or be moving with constant velocity (speed and direction). PS.FM.1.19
20. Students understand that constant acceleration occurs when the change in an object's instantaneous velocity is the same for equal successive time intervals. PS.FM.1.20
21. Students understand that motion can be represented by position vs. time and velocity vs. time graphs. PS.FM.1.21
22. Students understand that specifics about the speed, direction and change in motion can be determined by interpreting such graphs. PS.FM.1.22
23. Students understand that motion can be investigated by collecting and analyzing data in the laboratory and should include constant velocity as well as constant acceleration. PS.FM.1.23
24. Students understand that technology can enhance motion exploration and investigation through video analysis, the use of motion detectors and graphing data for analysis. PS.FM.1.24
25. Students understand that objects that move with constant velocity and have no acceleration form a straight line (not necessarily horizontal) on a position vs. time graph. PS.FM.1.25
26. Students understand that objects that are at rest will form a horizontal line on a position vs. time graph. PS.FM.1.26
27. Students understand that objects that are accelerating will show a curved line on a position vs. time graph. PS.FM.1.27
28. Students understand that velocity can be calculated by determining the slope of a position vs. time graph. PS.FM.1.28
29. Students understand that positive slopes on position vs. time graphs indicate motion in a positive direction. PS.FM.1.29
30. Students understand that negative slopes on position vs. time graphs indicate motion in a negative direction. PS.FM.1.30
31. Students understand that constant acceleration is represented by a straight line (not necessarily horizontal) on a velocity vs. time graph. PS.FM.1.31
32. Students understand that objects that have no acceleration (at rest or moving at a constant velocity) will have a horizontal line for a velocity vs. time graph. PS.FM.1.32
33. Students understand that average acceleration can be determined from the slope of a velocity vs. time graph. PS.FM.1.33

2. Forces PS.FM.2

   1. Students understand that force is a vector quantity, having both magnitude and direction. PS.FM.2.1

   2. Students understand that force diagrams are useful tools for visualizing and analyzing the forces acting on objects. PS.FM.2.2
   3. Students understand that the (SI) unit of force is a newton. PS.FM.2.3
   4. Students understand that one newton of net force will cause a 1 kg object to experience an acceleration of 1 m/s^2. PS.FM.2.4
   5. Students understand that a newton can also be represented as $kg \cdot m/s^2$. PS.FM.2.5
   6. Students understand that the net force can be determined by one-dimensional vector addition. PS.FM.2.6
   7. Students understand that gravitational force (weight) can be calculated from mass, but all other forces will only be quantified from force diagrams. PS.FM.2.7
   8. Students understand that friction is a force that opposes motion. PS.FM.2.8
   9. Students understand that a normal force exists between two solid objects when their surfaces are pressed together due to other forces acting on one or both objects (e.g., a solid sitting on or sliding across a table, a ladder leaning against a wall, a ball hitting a bat). PS.FM.2.9
   10. Students understand that a normal force is always a push directed at right angles from the surfaces of the interacting objects. PS.FM.2.10
   11. Students understand that a tension force occurs when a non-slack rope, wire, cord or similar device pulls on another object. PS.FM.2.11
   12. Students understand that the stronger the field, the greater the force exerted on objects placed in the field. PS.FM.2.12
   13. Students understand that the field of an object is always there even if the object is not interacting with anything else. PS.FM.2.13
   14. Students understand that the gravitational force (weight) of an object is proportional to its mass. PS.FM.2.14
   15. Students understand that weight, F_g, can be calculated from the equation F_g = mg, where g is the gravitational field strength of an object which is equal to 9.8 N/kg or 9.8 m/s^2 on the surface of Earth. PS.FM.2.15

3. Dynamics (how forces affect motion) PS.FM.3
   1. Students understand that the focus of the content is to develop a conceptual understanding of the laws of motion to explain and predict changes in motion, not to name or recite a memorized definition. PS.FM.3.1
   2. Students understand that when the vector sum of the forces (net force, F_{net}) acting on an object is zero, the object does not accelerate. PS.FM.3.2
   3. Students understand that for an object that is moving, this means the object will remain moving without changing its speed or direction. PS.FM.3.3
   4. Students understand that for an object that is not moving, the object will continue to remain stationary. PS.FM.3.4

5. Students understand that an object will accelerate (increase or decrease its speed or change its direction of motion) when an unbalanced net force acts on it. PS.FM.3.5
6. Students understand that the rate at which an object changes its speed or direction (acceleration) is proportional to the vector sum of the forces (net force, F_{net}) and inversely proportional to the mass (a = F_{net}/m). PS.FM.3.6
7. Students understand that these laws will be applied to systems consisting of a single object upon which multiple forces act. PS.FM.3.7
8. Students understand that vector addition will be limited to one dimension (positive and negative). PS.FM.3.8
9. Students understand that while both horizontal and vertical forces can be acting on an object simultaneously, for this level, one of the dimensions must have a net force of zero. PS.FM.3.9
10. Students understand that a force is an interaction between two objects. Both objects in the interaction experience an equal amount of force, but in opposite directions. PS.FM.3.10
11. Students understand that interacting force pairs are often confused with balanced forces. PS.FM.3.11
12. Students understand that interacting force pairs can never cancel each other out because they always act on different objects. PS.FM.3.12
13. Students understand that naming the force (e.g., gravity, friction) does not identify the two objects involved in the interacting force pair. PS.FM.3.13
14. Students understand that objects involved in an interacting force pair can be easily identified by using the format "A acts on B so B acts on A." For example, the truck hits the sign therefore the sign hits the truck with an equal force in the opposite direction. Earth pulls the book down so the book pulls Earth up with an equal force. PS.FM.3.14
15. Students understand that in Physics, all laws will be applied to systems of many objects. PS.FM.3.15

The Universe

1. History of the Universe PS.U.1
    1. The student will understand that the big bang model is a broadly accepted theory for the origin and evolution of our universe. PS.U.1.1
        a. It postulates that 12 to 14 billion years ago, the portion of the universe seen today was only a few millimeters across. PS.U.1.1.A
    2. The student will understand that according to the "big bang" theory, the contents of the known universe expanded explosively into existence from a hot, dense state 13.7 billion years ago. PS.U.1.2
    3. The student will understand that after the big bang, the universe expanded quickly (and continues to expand) and then cooled down enough for atoms to form. PS.U.1.3
    4. The student will understand that gravity pulled the atoms together into gas clouds that eventually became stars, which comprise young galaxies. PS.U.1.4
    5. The student will understand that foundations for the big bang model can be included to introduce the supporting evidence for the expansion of the known universe (e.g., Hubble's law and red shift or cosmic microwave background radiation). PS.U.1.5
    6. The student will understand that technology provides the basis for many new discoveries related to space and the universe. PS.U.1.6
    7. The student will understand that visual, radio and x-ray telescopes collect information from across the entire electromagnetic spectrum; computers are used to manage data and complicated computations; space probes send back data and materials from remote parts of the solar system; and accelerators provide subatomic particle energies that simulate conditions in the stars and in the early history of the universe before stars formed. PS.U.1.7
2. Galaxies PS.U.2
    1. Students understand that a galaxy is a group of billions of individual stars, star systems, star clusters, dust and gas bound together by gravity. PS.U.2.1
    2. Students understand that there are billions of galaxies in the universe (NAEP 2009, page 52), and they are classified by size and shape. PS.U.2.2
    3. Students understand that most observed galaxies are classified as elliptical, spiral and irregular. PS.U.2.3
    4. Students understand that the Milky Way is a spiral galaxy. PS.U.2.4
    5. Students understand that the Milky Way has more than 100 billion stars and a diameter of more than 100,000 light years. PS.U.2.5
    6. Students understand that at the center of the Milky Way is a massive black hole around which is a collection of stars bulging outward from the disk, from which extend spiral arms of gas, dust and most of the young stars. PS.U.2.6
    7. Students understand that the solar system is part of the Milky Way galaxy. PS.U.2.7

8. Students understand that Hubble's law states that galaxies that are farther away have a greater red shift, so the speed at which a galaxy is moving away is proportional to its distance from Earth. PS.U.2.8
9. Students understand that red shift is a phenomenon due to Doppler shifting, so the shift of light from a galaxy to the red end of the spectrum indicates that the galaxy and the observer are moving farther away from one another. PS.U.2.9
10. Students understand that Doppler shifting is also found in the Energy and Waves section of this course. PS.U.2.10

3. Stars PS.U.3
   1. Students understand that early in the formation of the universe, stars coalesced out of clouds of hydrogen and helium and clumped together by gravitational attraction into galaxies. PS.U.3.1
   2. Students understand that when heated to a sufficiently high temperature by gravitational attraction, stars begin nuclear reactions, which convert matter to energy and fuse the lighter elements into heavier ones. PS.U.3.2
   3. Students understand that all elements, except for hydrogen and some helium and lithium, originated from nuclear fusion reactions of stars. PS.U.3.3
   4. Students understand that stars are classified by their color, size, luminosity and mass. PS.U.3.4
   5. Students understand that a Hertzprung-Russell diagram can be used to estimate the sizes of stars and predict how stars will evolve. PS.U.3.5
   6. Students understand that most stars fall on the main sequence of the H-R diagram, a diagonal band running from the bright hot stars on the upper left to the dim cool stars on the lower right. PS.U.3.6
   7. Students understand that stars like the sun will eventually collapse to become a white dwarf, while more massive stars will collapse to form neutron stars or black holes. PS.U.3.7
   8. Students understand that for stars like the sun, this process of collapse will produce a nebula. PS.U.3.8
   9. Students understand that more massive stars will collapse with a supernova explosion. PS.U.3.9
   10. Students understand that the gas ejected from the system during the end stages of the star's life may eventually coalesce under gravity to form new stars, and the stellar life cycle with begin again. PS.U.3.10