

# General Science Subject Matter Requirements

## Content Domains for Subject Matter Understanding and Skill in General Science

### Domain 1. Scientific Practices, Engineering Design and Applications, and Crosscutting Concepts

#### 1.1 Understand scientific practices.

- a. Demonstrate knowledge of how to ask questions that can be addressed by scientific investigation, help further understanding of observed phenomena, and help clarify scientific explanations and relationships.
- b. Apply knowledge of the development of important scientific ideas and models over time and of how history shows that evaluating a model's merits and limitations leads to its improvement.
- c. Apply knowledge of planning and conducting scientific investigations, including safety considerations and the use of appropriate tools and technology.
- d. Apply modeling and the mathematical concepts of statistics and probability to the analysis and interpretation of data, including analysis of errors and their origins.
- e. Demonstrate the ability to analyze scientific data and information and draw appropriate and logical conclusions.
- f. Use mathematics (e.g., dimensional analysis, statistics, proportional thinking) and computational thinking to represent and solve scientific problems and to assess scientific simulations.
- g. Demonstrate the ability to construct and analyze scientific explanations.
- h. Demonstrate the ability to evaluate scientific arguments in terms of their supporting evidence and reasoning.
- i. Demonstrate knowledge of the ability to obtain, evaluate, interpret, and communicate scientific information (e.g., determining central ideas, integrating information from multiple sources, evaluating the validity of claims, using multiple formats to communicate scientific results).

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Appendix F – Science and Engineering Practices, Practices 1–8)

#### 1.2 Understand engineering practices, design, and applications.

- a. Apply knowledge of engineering practices to define problems, determine specifications of designed systems, and identify constraints.
- b. Evaluate design solutions in terms of their scientific and engineering constraints and the environmental, social, and cultural impacts of these solutions.
- c. Apply knowledge of the roles of models (e.g., mathematical, physical, computer simulations) in the engineering design process.
- d. Demonstrate knowledge of the process used to optimize a design solution (e.g., prioritizing criteria, refining a design due to test results).
- e. Apply knowledge of the interdependence of science, engineering, and technology (e.g., in agriculture, health care, and communications).

- f. Demonstrate knowledge of the influence of engineering, technology, and science on society and the natural world (e.g., in land use, transportation, and energy production).

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Appendix F – Science and Engineering Practices, Practices 1–8 and Engineering Design, ETS1.A, ETS1.B, ETS1.C, ETS2.A, ETS2.B)

### **1.3 Understand crosscutting concepts among the sciences and engineering.**

- a. Apply knowledge of patterns characteristic of natural phenomena and engineered systems.
- b. Analyze cause-and-effect relationships and their mechanisms in natural phenomena and engineered systems.
- c. Apply knowledge of the concepts of scale, proportion, and quantity to describe and compare natural and engineered systems.
- d. Apply knowledge of how systems are defined and studied and of how system models are used to make predictions.
- e. Apply knowledge of the flow, cycling, and conservation of energy and matter to analyze natural and engineered systems.
- f. Analyze the relationship between structure and function in natural and engineered systems.
- g. Analyze the factors contributing to stability and change in systems (e.g., static and dynamic equilibrium, feedback) and the rates at which systems change.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Appendix G – Crosscutting Concepts, Concepts 1–7)

## **Domain 2. Physical Sciences**

### **2.1 Understand structure and properties of matter.**

- a. Analyze the basic substructure of an atom (i.e., protons, neutrons, and electrons).
- b. Differentiate between atoms and their isotopes, ions, molecules, elements, and compounds.
- c. Apply knowledge of the development and organization of the periodic table and predict the properties of elements on the basis of their positions in the periodic table.
- d. Demonstrate knowledge of nuclear forces that hold nuclei together and are responsible for nuclear processes (e.g., fission, fusion) and radioactivity (e.g., alpha, beta, and gamma decay).
- e. Demonstrate knowledge of the characteristics of the different states of matter.
- f. Apply knowledge of physical changes of matter and physical properties of matter.
- g. Demonstrate knowledge of the physical and chemical characteristics, including pH, of acids, bases, and neutral solutions.
- h. Apply knowledge of the physical and chemical properties of water.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS1.A)

## **2.2 Understand chemical reactions and biochemistry.**

- a. Recognize that chemical reactions can be understood in terms of the collisions between ions, atoms, or molecules and the rearrangement of particles.
- b. Apply knowledge of the principles of conservation of matter to chemical reactions, including balancing chemical equations.
- c. Describe the effect of temperature, pressure, and concentration on chemical equilibrium (Le Chatelier's principle) and reaction rate.
- d. Analyze chemical bonding with respect to an element's position in the periodic table.
- e. Demonstrate knowledge of the central role of carbon in the chemistry of living systems.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS1.B)

## **2.3 Understand motion and stability: forces and interactions.**

- a. Apply knowledge of Newton's laws of motion and law of universal gravitation and recognize the relationship between these laws and the laws of conservation of energy and momentum.
- b. Demonstrate knowledge of the definition of pressure and how pressure relates to fluid flow and buoyancy, including describing everyday phenomena (e.g., the functioning of heart valves, atmospheric pressure).
- c. Identify the separate forces that act on a system (e.g., gravity, tension/compression, normal force, friction), describe the net force on the system, and describe the effect on the stability of the system.
- d. Analyze displacement, motion, and forces using models (e.g., vector, graphic representation, equations).
- e. Identify fundamental forces, including gravity, nuclear forces, and electromagnetic forces (magnetic and electric), and recognize their roles in nature, such as the role of gravity in maintaining the structure of the universe.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS2.A, PS2.B, PS3.C)

## **2.4 Understand waves and their applications in technologies for information transfer.**

- a. Compare the characteristics of mechanical and electromagnetic waves (e.g., transverse/longitudinal, travel through various media, relative speed).
- b. Demonstrate knowledge of the relationship between wave frequency, wavelength, and amplitude and energy.
- c. Demonstrate knowledge of resonance and of the reflection, refraction, and transmission of waves.
- d. Apply knowledge of electromagnetic radiation, including analyzing evidence that supports the wave and particle models that explain the properties of electromagnetic radiation.
- e. Evaluate evidence that indicates that certain wavelengths of electromagnetic radiation may affect living cells.
- f. Demonstrate knowledge of how lenses are used in simple optical systems, including the camera, telescope, microscope, and eye.
- g. Compare and contrast the transmission, reflection, and absorption of light in matter.

- h. Demonstrate knowledge of how energy and information are transferred by waves without mass transfer, including recognizing technology that employ this phenomenon.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS4.A, PS4.B, PS4.C, Grade 8 Physical Sciences MS-PS4.B)

## **2.5 Understand energy.**

- a. Demonstrate knowledge of kinetic and potential energy.
- b. Demonstrate knowledge of the ways in which energy manifests itself at the macroscopic level (e.g., motion, sound, light, thermal energy).
- c. Demonstrate knowledge of the principle of conservation of energy, including analyzing energy transfers.
- d. Demonstrate knowledge of how the transfer of energy as heat is related to changes in temperature and interpret the direction of heat flow in a system.
- e. Apply knowledge of heat transfer by conduction, convection, and radiation, including analyzing examples of each mode of heat transfer.
- f. Analyze how chemical energy in fuel is transformed to heat.
- g. Demonstrate knowledge of the energy changes that accompany changes in states of matter.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS3.A, PS3.B, PS3.D)

## **2.6 Understand electricity and magnetism.**

- a. Demonstrate knowledge of electrostatic and magnetostatic phenomena, including evaluating examples of each type of phenomenon.
- b. Predict charges or poles on the basis of attraction/repulsion observations.
- c. Relate electric currents to magnetic fields and describe the application of these relationships, such as in electromagnets, electric current generators, motors, and transformers.
- d. Demonstrate knowledge of how energy is stored and can change in electric and magnetic fields.
- e. Interpret simple series and parallel circuits.
- f. Demonstrate knowledge of the definitions of power, voltage differences, current, and resistance and calculate their values in simple circuits.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Physical Sciences: PS2.B, PS3.A, PS3.C)

## **Domain 3. Life Sciences**

### **3.1 Understand the structure and function of cells.**

- a. Demonstrate understanding that a small subset of elements (C, H, O, N, P, S) makes up most of the chemical compounds in living organisms by combining in many ways.
- b. Recognize and differentiate the structure and function of molecules in living organisms, including carbohydrates, lipids, proteins, and nucleic acids.

- c. Demonstrate knowledge of evidence that living things are made of cells.
- d. Analyze the similarities and differences among prokaryotic and eukaryotic cells and viruses.
- e. Demonstrate knowledge of organelles and their structures and functions in the cell and how differences in the structure of cells are related to cell function.
- f. Demonstrate knowledge of the process and significance of protein synthesis.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Life Sciences: LS1.A)

### **3.2 Understand growth, development, and energy flow in organisms.**

- a. Demonstrate knowledge of the importance of mitosis and meiosis as processes of cellular and organismal reproduction.
- b. Compare single-celled and multicellular organisms, including the role of cell differentiation in the development of multicellular organisms.
- c. Recognize the hierarchical levels of organization (e.g., cells, tissues, organs, systems, organisms) in plants and animals.
- d. Demonstrate knowledge of the major anatomical structures and life processes (e.g., reproduction, photosynthesis, cellular respiration, transpiration) of various plant groups.
- e. Demonstrate knowledge of feedback mechanisms responsible for maintaining homeostasis in animals, including humans, and plants, including the anatomical structures and systems involved in regulating internal conditions.
- f. Analyze the processes of cellular respiration (anaerobic and aerobic).
- g. Demonstrate knowledge of the conversion, flow, and storage of energy in the cell.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Life Sciences: LS1.B, LS1.C)

### **3.3 Understand ecosystems: interactions, energy, and dynamics.**

- a. Demonstrate knowledge of the abiotic and biotic factors in an ecosystem and their relationship to the growth of individual organisms.
- b. Demonstrate knowledge of the interrelationships within and among ecosystems and recognize factors that affect population types, size, and carrying capacity in ecosystems (e.g., availability of biotic and abiotic resources, predation, competition, disease).
- c. Apply knowledge of energy flow, nutrient cycling, and matter transfer in ecosystems (e.g., food webs, biogeochemical cycles), including recognizing the roles played by photosynthesis and aerobic and anaerobic respiration.
- d. Demonstrate knowledge of possible solutions for minimizing human impact on ecosystem resources and biodiversity.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Life Sciences: LS2.A, LS2.B, LS2.C)

### **3.4 Understand heredity: inheritance and variation of traits.**

- a. Demonstrate knowledge of the roles of DNA (deoxyribonucleic acid) molecules in cells (e.g., storing genetic information, coding for proteins, regulatory functions, structural functions).

- b. Apply knowledge of the structure of DNA and the process of DNA replication.
- c. Apply knowledge of how genetic variation may be the result of errors that occur during DNA replication or mutations caused by environmental factors and explain their causes and effects.
- d. Demonstrate knowledge of how the coding of DNA controls the expression of traits by genes and influences essential life functions (e.g., how DNA determines protein structure and other heritable genetic variations).
- e. Demonstrate knowledge of the relationship between genes and their interaction with the environment in terms of organisms' development and functions.
- f. Compare and contrast sexual and asexual reproduction.
- g. Apply knowledge of genotypes and phenotypes and the inheritance of traits that are determined by one or more genes (e.g., dominant, recessive, and sex-linked alleles; incomplete dominance).
- h. Solve problems from representations of monohybrid and dihybrid crosses.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Life Sciences: LS3.A, LS3.B)

### **3.5 Understand biological evolution: unity and diversity.**

- a. Apply knowledge of anatomical, embryological, and genetic evidence of biological evolution and common ancestry and interpret branching diagrams (cladograms).
- b. Demonstrate knowledge of the theory of natural selection, including how genetic variation and its expression leads to differences in characteristics among individuals in a population, adaptation, speciation, and extinction.
- c. Demonstrate knowledge of major events that affected the evolution of life on Earth (e.g., climate changes, asteroid impacts).
- d. Demonstrate knowledge of technologies that allow humans to influence the genetic traits of organisms.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Life Sciences: LS4.A, LS4.B, LS4.C)

## **Domain 4. Earth and Space Sciences**

### **4.1 Understand Earth's place in the universe.**

- a. Demonstrate knowledge of the evidence for the Big Bang model (e.g., light spectra, motion of distant galaxies, spectra of primordial radiation).
- b. Demonstrate knowledge of how astronomical instruments are used to collect data and how astronomical units are used to describe distances.
- c. Demonstrate knowledge of the factors that contribute to a star's color, size, and luminosity and how a star's light spectrum and brightness can be used to identify compositional elements, movements, and distance from Earth.
- d. Demonstrate knowledge of nuclear fusion in stars, including the relationship between a star's mass and stage of its lifetime and the elements produced.
- e. Demonstrate knowledge of the formation and structure of the solar system, its place in the Milky Way galaxy, and the characteristics of various objects in the solar system.

- f. Recognize how evidence from the study of lunar rocks, asteroids, and meteorites provides information about Earth's formation and history.
- g. Compare and contrast uniformitarianism and catastrophism.
- h. Demonstrate knowledge of the regular and predictable patterns of movements of stars, planets, and the moon and their effects on Earth's systems (e.g., seasons, eclipses, tides).
- i. Apply knowledge of how Kepler's laws are used to predict the motion of orbiting objects.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Earth and Space Sciences: ESS1.A, ESS1.B, ESS1.C)

#### **4.2 Understand Earth's materials and systems and surface processes.**

- a. Recognize various forms of evidence (e.g., seismic waves, iron meteorites, magnetic field data) that led to the current model of Earth's structure (i.e., hot but solid inner core, a liquid outer core, a solid mantle and crust).
- b. Demonstrate knowledge of the dynamic processes of erosion, deposition, and transport, including evidence for connections between these processes and the formation of Earth's materials.
- c. Demonstrate knowledge of relative and absolute dating techniques, including how half-lives are used in radiometric dating and of how evidence from rock strata is used to establish the geologic timescale.
- d. Recognize the factors that can alter the flow of energy into and out of Earth's systems (e.g., tectonic events, ocean circulation, volcanic activity, vegetation).
- e. Relate the abundance of liquid water on Earth's surface and water's physical and chemical properties to the dynamic processes shaping the planet's materials and surface.
- f. Demonstrate knowledge of surficial processes that form geographic features of Earth's surface (e.g., mechanical, chemical, and biological weathering).

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Earth and Space Sciences: ESS2.A, ESS2.C)

#### **4.3 Understand plate tectonics and large-scale system interactions.**

- a. Demonstrate knowledge of the evidence for plate tectonics (e.g., the ages of crustal rocks, distribution of fossils and rocks, continental shapes) and relate plate movements to continental and ocean-floor features.
- b. Demonstrate knowledge of the thermal processes driving plate movement and relate density and buoyancy to plate tectonics.
- c. Demonstrate knowledge of the differences between types of plate boundaries, causes of volcanoes, earthquakes, and how Earth's resources relate to tectonic processes.
- d. Demonstrate knowledge of the factors contributing to the extent of damage caused by an earthquake (e.g., epicenter, focal mechanism, distance, geologic substrate).

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Earth and Space Sciences: ESS2.B)

#### **4.4 Understand weather and climate.**

- a. Demonstrate knowledge of the water cycle and the interrelationships of surface and subsurface reservoirs.
- b. Demonstrate knowledge of the causes of daily, seasonal, and climatic changes and analyze the uneven heating of Earth by the sun.
- c. Analyze the effects of air movements on weather and interpret weather maps to predict weather patterns.
- d. Demonstrate knowledge of the energy transfer processes of convection, conduction, and radiation in relation to the atmosphere/ocean and Earth's interior structure.
- e. Demonstrate knowledge of the mechanisms and the significance of the greenhouse effect on Earth, including the roles of the oceans and biosphere in absorbing greenhouse gases.
- f. Demonstrate knowledge of human activities and their impact on global climate change.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Earth and Space Sciences: ESS2.D)

#### **4.5 Understand natural resources and natural hazards.**

- a. Demonstrate knowledge of renewable and nonrenewable energy resources (e.g., fossil fuels, nuclear fuels, solar, biomass).
- b. Demonstrate knowledge of Earth's materials as resources (e.g., rocks, minerals, soils, water) that have a global distribution affected by past and current geological processes.
- c. Analyze extraction and recycling processes in relation to energy, cost, and demand.
- d. Demonstrate knowledge of sustainable uses of resources with respect to utility, cost, and demand.
- e. Demonstrate knowledge of the effects of natural hazards (e.g., earthquakes, landslides, floods) on natural and human-made habitats.
- f. Demonstrate knowledge of how the availability of natural resources and the existence of natural hazards and other geologic events have influenced the development of human society.

(Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve, Grades Nine through Twelve, Earth and Space Sciences: ESS3.A, ESS3.B)

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