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# Science Standards of Learning

for  
Virginia  
Public Schools



Board of Education  
Commonwealth of Virginia

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# Science Standards of Learning

## for Virginia Public Schools

**Adopted in January 2010 by the  
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## **Preface**

The Standards of Learning in this publication represent a significant development in public education in Virginia. These standards focus on the scientific knowledge and skills all students need for the future, and they have been aligned with national expectations for postsecondary success.

The Standards of Learning provide a framework for instructional programs designed to raise the academic achievement of all students in Virginia and are an important part of Virginia's efforts to provide challenging educational programs in the public schools.

The Standards of Learning set reasonable targets and expectations for what teachers must teach and students must learn. The standards are not intended to encompass the entire curriculum for a given grade level or course or to prescribe how the content should be taught; the standards are to be incorporated into a broader, locally designed curriculum. Teachers are encouraged to go beyond the standards and select instructional strategies and assessment methods appropriate for their students.

The Standards of Learning are recognized as a model for other states. They were developed through a series of public hearings and the efforts of parents, teachers, representatives from higher education, and business and industry leaders. The standards set clear, concise, and measurable academic expectations for young people. Parents are encouraged to work with their children to help them achieve these academic standards.

A major goal of Virginia's educational agenda is to create an excellent statewide system of public education that meets the needs of all young people in Virginia. These Standards of Learning chart the course for achieving that objective.

## **Introduction**

The *Science Standards of Learning* for Virginia Public Schools identify academic content for essential components of the science curriculum at different grade levels. Standards are identified for kindergarten through grade five, for middle school, and for a core set of high school courses — Earth Science, Biology, Chemistry, and Physics. Throughout a student’s science schooling from kindergarten through grade six, content strands, or topics are included. The Standards of Learning in each strand progress in complexity as they are studied at various grade levels in grades K-6, and are represented indirectly throughout the high school courses. These strands are

- Scientific Investigation, Reasoning, and Logic;
- Force, Motion, and Energy;
- Matter;
- Life Processes;
- Living Systems;
- Interrelationships in Earth/Space Systems;
- Earth Patterns, Cycles, and Change; and
- Earth Resources.

Five key components of the science standards that are critical to implementation and necessary for student success in achieving science literacy are 1) Goals; 2) K-12 Safety; 3) Instructional Technology; 4) Investigate and Understand; and 5) Application. It is imperative to science instruction that the local curriculum consider and address how these components are incorporated in the design of the kindergarten through high school science program.

## **Goals**

The purposes of scientific investigation and discovery are to satisfy humankind’s quest for knowledge and understanding and to preserve and enhance the quality of the human experience. Therefore, as a result of science instruction, students will be able to achieve the following objectives:

1. Develop and use an experimental design in scientific inquiry.
2. Use the language of science to communicate understanding.
3. Investigate phenomena using technology.
4. Apply scientific concepts, skills, and processes to everyday experiences.
5. Experience the richness and excitement of scientific discovery of the natural world through the collaborative quest for knowledge and understanding.
6. Make informed decisions regarding contemporary issues, taking into account the following:
  - public policy and legislation;

- economic costs/benefits;
  - validation from scientific data and the use of scientific reasoning and logic;
  - respect for living things;
  - personal responsibility; and
  - history of scientific discovery.
7. Develop scientific dispositions and habits of mind including:
    - curiosity;
    - demand for verification;
    - respect for logic and rational thinking;
    - consideration of premises and consequences;
    - respect for historical contributions;
    - attention to accuracy and precision; and
    - patience and persistence.
  8. Develop an understanding of the interrelationship of science with technology, engineering and mathematics.
  9. Explore science-related careers and interests.

### **K-12 Safety**

In implementing the *Science Standards of Learning*, teachers must be certain that students know how to follow safety guidelines, demonstrate appropriate laboratory safety techniques, and use equipment safely while working individually and in groups.

Safety must be given the highest priority in implementing the K-12 instructional program for science. Correct and safe techniques, as well as wise selection of experiments, resources, materials, and field experiences appropriate to age levels, must be carefully considered with regard to the safety precautions for every instructional activity. Safe science classrooms require thorough planning, careful management, and constant monitoring of student activities. Class enrollment should not exceed the designed capacity of the room.

Teachers must be knowledgeable of the properties, use, and proper disposal of all chemicals that may be judged as hazardous prior to their use in an instructional activity. Such information is referenced through Materials Safety Data Sheets (MSDS). The identified precautions involving the use of goggles, gloves, aprons, and fume hoods must be followed as prescribed.

While no comprehensive list exists to cover all situations, the following should be reviewed to avoid potential safety problems. Appropriate safety procedures should be used in the following situations:

- observing wildlife; handling living and preserved organisms; and coming in contact with natural hazards, such as poison ivy, ticks, mushrooms, insects, spiders, and snakes;
- engaging in field activities in, near, or over bodies of water;
- handling glass tubing and other glassware, sharp objects, and labware;
- handling natural gas burners, Bunsen burners, and other sources of flame/heat;
- working in or with direct sunlight (sunburn and eye damage);
- using extreme temperatures and cryogenic materials;
- handling hazardous chemicals including toxins, carcinogens, and flammable and explosive materials;
- producing acid/base neutralization reactions/dilutions;
- producing toxic gases;
- generating/working with high pressures;
- working with biological cultures including their appropriate disposal and recombinant DNA;
- handling power equipment/motors;
- working with high voltage/exposed wiring; and
- working with laser beam, UV, and other radiation.

The use of human body fluids or tissues is generally prohibited for classroom lab activities. Further guidance from the following sources may be referenced:

- OSHA (Occupational Safety and Health Administration);
- ISEF (International Science and Engineering Fair) rules; and
- public health departments' and school divisions' protocols.

### **Instructional Technology**

The use of current and emerging technologies is essential to the K-12 science instructional program. Specifically, technology must accomplish the following:

- Assist in improving every student's functional literacy. This includes improved communication through reading/information retrieval (the use of telecommunications), writing (word processing), organization and analysis of data (databases, spreadsheets, and graphics programs), presentation of one's ideas (presentation software), and resource management (project management software).
- Be readily available and regularly used as an integral and ongoing part of the delivery and assessment of instruction.
- Include instrumentation oriented toward the instruction and learning of science concepts, skills, and processes. Technology, however, should not be limited to traditional instruments of science, such as microscopes, labware, and data-collecting apparatus, but should also include computers, robotics, video-microscopes, graphing calculators,

probeware, geospatial technologies, online communication, software and appropriate hardware, as well as other emerging technologies.

- Be reflected in the “instructional strategies” generally developed at the school division level.

In most cases, the application of technology in science should remain “transparent” unless it is the actual focus of the instruction. One must expect students to “do as a scientist does” and not simply hear about science if they are truly expected to explore, explain, and apply scientific concepts, skills, and processes.

As computer/technology skills are essential components of every student’s education, it is important that teaching these skills is a shared responsibility of teachers of all disciplines and grade levels.

### **Investigate and Understand**

Many of the standards in the *Science Standards of Learning* begin with the phrase “Students will investigate and understand.” This phrase was chosen to communicate the range of rigorous science skills and knowledge levels embedded in each standard. Limiting a standard to one observable behavior, such as “describe” or “explain,” would have narrowed the interpretation of what was intended to be a rich, highly rigorous, and inclusive content standard.

“Investigate” refers to scientific methodology and implies systematic use of the following inquiry skills:

- observing;
- classifying and sequencing;
- communicating;
- measuring;
- predicting;
- hypothesizing;
- inferring;
- defining, controlling, and manipulating variables in experimentation;
- designing, constructing, and interpreting models; and
- interpreting, analyzing, and evaluating data.

“Understand” refers to various levels of knowledge application. In the *Science Standards of Learning*, these knowledge levels include the ability to:

- recall or recognize important information, key definitions, terminology, and facts;
- explain the information in one’s own words, comprehend how the information is related to other key facts, and suggest additional interpretations of its meaning or importance;



- apply the facts and principles to new problems or situations, recognizing what information is required for a particular situation, using the information to explain new phenomena, and determining when there are exceptions;
- analyze the underlying details of important facts and principles, recognizing the key relations and patterns that are not always readily visible;
- arrange and combine important facts, principles, and other information to produce a new idea, plan, procedure, or product; and
- make judgments about information in terms of its accuracy, precision, consistency, or effectiveness.

Therefore, the use of “investigate and understand” allows each content standard to become the basis for a broad range of teaching objectives, which the school division will develop and refine to meet the intent of the *Science Standards of Learning*.

### **Application**

Science provides the key to understanding the natural world. The application of science to relevant topics provides a context for students to build their knowledge and make connections across content and subject areas. This includes applications of science among technology, engineering, and mathematics, as well as within other science disciplines. Various strategies can be used to facilitate these applications and to promote a better understanding of the interrelated nature of these four areas.

# Kindergarten

The kindergarten standards stress the use of basic science skills to explore common materials, objects, and living things and will begin the development of an understanding that scientific knowledge is based on evidence. Emphasis is placed on using the senses to gather information. Students are expected to develop skills in posing simple questions, measuring, sorting, classifying, and communicating information about the natural world. The science skills are an important focus as students learn about life processes and properties of familiar materials, such as magnets and water. Through phenomena including shadows, patterns of weather, and plant growth, students are introduced to the concept of change. The significance of natural resources and conservation is introduced in the kindergarten standards.

## Scientific Investigation, Reasoning, and Logic

- K.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which
- a) basic characteristics or properties of objects are identified by direct observation;
  - b) observations are made from multiple positions to achieve different perspectives;
  - c) a set of objects is sequenced according to size;
  - d) a set of objects is separated into two groups based on a single physical characteristic;
  - e) nonstandard units are used to measure the length, mass, and volume of common objects;
  - f) observations and predictions are made for an unseen member in a sequence of objects;
  - g) a question is developed and predictions are made from one or more observations;
  - h) observations are recorded;
  - i) picture graphs are constructed;
  - j) unusual or unexpected results in an activity are recognized; and
  - k) objects are described both pictorially and verbally.
- K.2 The student will investigate and understand that humans have senses that allow them to seek, find, take in, and react or respond to information in order to learn about their surroundings. Key concepts include
- a) the five senses and corresponding sensing organs; and
  - b) sensory descriptors used to describe common objects and phenomena.

## **Force, Motion, and Energy**

- K.3 The student will investigate and understand that magnets have an effect on some materials, make some things move without touching them, and have useful applications. Key concepts include
- a) magnetism and its effects; and
  - b) useful applications of magnetism.

## **Matter**

- K.4 The student will investigate and understand that the position, motion, and physical properties of an object can be described. Key concepts include
- a) colors of objects;
  - b) shapes and forms of objects;
  - c) textures and feel of objects;
  - d) relative sizes and weights of objects; and
  - e) relative positions and speed of objects.
- K.5 The student will investigate and understand that water flows and has properties that can be observed and tested. Key concepts include
- a) water occurs in different phases;
  - b) water flows downhill; and
  - c) some materials float in water, while others sink.

## **Life Processes**

- K.6 The student will investigate and understand the differences between living organisms and nonliving objects. Key concepts include
- a) all things can be classified as living or nonliving; and
  - b) living organisms have certain characteristics that distinguish them from nonliving objects including growth, movement, response to the environment, having offspring, and the need for food, air, and water.
- K.7 The student will investigate and understand basic needs and life processes of plants and animals. Key concepts include
- a) animals need adequate food, water, shelter, air, and space to survive;
  - b) plants need nutrients, water, air, light, and a place to grow to survive;
  - c) plants and animals change as they grow, have varied life cycles, and eventually die; and
  - d) offspring of plants and animals are similar but not identical to their parents or to one another.

## **Interrelationships in Earth/Space Systems**

- K.8 The student will investigate and understand that shadows occur when light is blocked by an object. Key concepts include
- a) shadows occur in nature when sunlight is blocked by an object; and
  - b) shadows can be produced by blocking artificial light sources.

## **Earth Patterns, Cycles, and Change**

- K.9 The student will investigate and understand that there are simple repeating patterns in his/her daily life. Key concepts include
- a) weather observations;
  - b) the shapes and forms of many common natural objects including seeds, cones, and leaves; and
  - c) animal and plant growth.
- K.10 The student will investigate and understand that change occurs over time and rates may be fast or slow. Key concepts include
- a) natural and human-made things may change over time; and
  - b) changes can be observed and measured.

## **Earth Resources**

- K.11 The student will investigate and understand that materials can be reused, recycled, and conserved. Key concepts include
- a) materials and objects can be used over and over again;
  - b) everyday materials can be recycled; and
  - c) water and energy conservation at home and in school helps ensure resources are available for future use.

# Grade One

The first-grade standards continue to stress basic science skills in understanding familiar objects and events. Students are expected to begin conducting simple experiments and be responsible for some of the planning. Students are introduced to the concept of classifying plants and animals based on simple characteristics. Emphasis is placed on the relationships among objects and their interactions with one another. Students are expected to know the basic relationships between the sun and Earth, and between seasonal changes and plant and animal activities. Students will also begin to develop an understanding of moving objects, simple solutions, and important natural resources.

## Scientific Investigation, Reasoning, and Logic

- 1.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which
- the senses are used to observe differences in physical properties;
  - observations are made from multiple positions to achieve a variety of perspectives and are repeated to ensure accuracy;
  - objects or events are classified and arranged according to characteristics or properties;
  - simple tools are used to enhance observations;
  - length, mass, volume, and temperature are measured using nonstandard units;
  - inferences are made and conclusions are drawn about familiar objects and events;
  - a question is developed from one or more observations;
  - predictions are made based on patterns of observations;
  - observations and data are recorded, analyzed, and communicated orally and with simple graphs, pictures, written statements, and numbers; and
  - simple investigations and experiments are conducted to answer questions.

## Force, Motion, and Energy

- 1.2 The student will investigate and understand that moving objects exhibit different kinds of motion. Key concepts include
- objects may have straight, circular, and back-and-forth motions;
  - objects may vibrate and produce sound; and
  - pushes or pulls can change the movement of an object.

## Matter

- 1.3 The student will investigate and understand how different common materials interact with water. Key concepts include
- some liquids will separate when mixed with water, but others will not;
  - some solids will dissolve in water, but others will not; and
  - some substances will dissolve more readily in hot water than in cold water.

## **Life Processes**

- 1.4 The student will investigate and understand that plants have basic life needs and functional parts and can be classified according to certain characteristics. Key concepts include
- plants need nutrients, air, water, light, and a place to grow;
  - basic parts of plants; and
  - plants can be classified based on a variety of characteristics.
- 1.5 The student will investigate and understand that animals, including humans, have basic needs and certain distinguishing characteristics. Key concepts include
- basic needs include adequate air, food, water, shelter, and space (habitat);
  - animals, including humans, have many different physical characteristics; and
  - animals can be classified according to a variety of characteristics.

## **Interrelationships in Earth/Space Systems**

- 1.6 The student will investigate and understand the basic relationships between the sun and Earth. Key concepts include
- the sun is the source of energy and light that warms the land, air, and water; and
  - the sun's relative position in the morning is east and in the late afternoon is west.

## **Earth Patterns, Cycles, and Change**

- 1.7 The student will investigate and understand weather and seasonal changes. Key concepts include
- changes in temperature, light, and precipitation affect plants and animals, including humans;
  - there are relationships between daily and seasonal changes; and
  - changes in temperature, light, and precipitation can be observed and recorded over time.

## **Earth Resources**

- 1.8 The student will investigate and understand that natural resources are limited. Key concepts include
- identification of natural resources;
  - factors that affect air and water quality; and
  - recycling, reusing, and reducing consumption of natural resources.

## Grade Two

The second-grade standards continue to focus on using a broad range of science skills in understanding the natural world. Making detailed observations, drawing conclusions, and recognizing unusual or unexpected data are stressed as skills needed for using and validating information. Measurement in both English and metric units is stressed. The idea of living systems is introduced through habitats and the interdependence of living and nonliving things. The concept of change is explored in phases of matter, life cycles, weather patterns, and seasonal effects on plants and animals.

### **Scientific Investigation, Reasoning, and Logic**

- 2.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which
- a) observations and predictions are made and questions are formed;
  - b) observations are differentiated from personal interpretation;
  - c) observations are repeated to ensure accuracy;
  - d) two or more characteristics or properties are used to classify items;
  - e) length, volume, mass, and temperature are measured in metric units and standard English units using the proper tools;
  - f) time is measured using the proper tools;
  - g) conditions that influence a change are identified and inferences are made;
  - h) data are collected and recorded, and bar graphs are constructed using numbered axes;
  - i) data are analyzed, and unexpected or unusual quantitative data are recognized;
  - j) conclusions are drawn;
  - k) observations and data are communicated;
  - l) simple physical models are designed and constructed to clarify explanations and show relationships; and
  - m) current applications are used to reinforce science concepts.

### **Force, Motion, and Energy**

- 2.2 The student will investigate and understand that natural and artificial magnets have certain characteristics and attract specific types of metals. Key concepts include
- a) magnetism, iron, magnetic/nonmagnetic, poles, attract/repel; and
  - b) important applications of magnetism.

### **Matter**

- 2.3 The student will investigate and understand basic properties of solids, liquids, and gases. Key concepts include
- a) identification of distinguishing characteristics of solids, liquids, and gases;
  - b) measurement of the mass and volume of solids and liquids; and
  - c) changes in phases of matter with the addition or removal of energy.

### **Life Processes**

- 2.4 The student will investigate and understand that plants and animals undergo a series of orderly changes as they mature and grow. Key concepts include
- a) animal life cycles; and
  - b) plant life cycles.

### **Living Systems**

- 2.5 The student will investigate and understand that living things are part of a system. Key concepts include
- a) living organisms are interdependent with their living and nonliving surroundings;
  - b) an animal's habitat includes adequate food, water, shelter or cover, and space;
  - c) habitats change over time due to many influences; and
  - d) fossils provide information about living systems that were on Earth years ago.

### **Interrelationships in Earth/Space Systems**

- 2.6 The student will investigate and understand basic types, changes, and patterns of weather. Key concepts include
- a) identification of common storms and other weather phenomena;
  - b) the uses and importance of measuring, recording, and interpreting weather data; and
  - c) the uses and importance of tracking weather data over time.

### **Earth Patterns, Cycles, and Change**

- 2.7 The student will investigate and understand that weather and seasonal changes affect plants, animals, and their surroundings. Key concepts include
- a) effects of weather and seasonal changes on the growth and behavior of living things; and
  - b) weathering and erosion of land surfaces.

### **Earth Resources**

- 2.8 The student will investigate and understand that plants produce oxygen and food, are a source of useful products, and provide benefits in nature. Key concepts include
- a) important plant products are identified and classified;
  - b) the availability of plant products affects the development of a geographic area;
  - c) plants provide oxygen, homes, and food for many animals; and
  - d) plants can help reduce erosion.



## Grade Three

The third-grade standards place increasing emphasis on conducting investigations. Students are expected to be able to develop questions, formulate simple hypotheses, make predictions, gather data, and use the metric system with greater precision. Using information to make inferences and draw conclusions becomes more important. In the area of physical science, the standards focus on simple and compound machines, energy, and a basic understanding of matter. Behavioral and physical adaptations are examined in relation to the life needs of animals. The notion of living systems is further explored in aquatic and terrestrial food chains and diversity in ecosystems. Patterns in the natural world are demonstrated in terms of the phases of the moon, tides, seasonal changes, the water cycle, and animal and plant life cycles. Geological concepts are introduced through the investigation of the components of soil.

### Scientific Investigation, Reasoning, and Logic

- 3.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which
- observations are made and are repeated to ensure accuracy;
  - predictions are formulated using a variety of sources of information;
  - objects with similar characteristics or properties are classified into at least two sets and two subsets;
  - natural events are sequenced chronologically;
  - length, volume, mass, and temperature are estimated and measured in metric and standard English units using proper tools and techniques;
  - time is measured to the nearest minute using proper tools and techniques;
  - questions are developed to formulate hypotheses;
  - data are gathered, charted, graphed, and analyzed;
  - unexpected or unusual quantitative data are recognized;
  - inferences are made and conclusions are drawn;
  - data are communicated;
  - models are designed and built; and
  - current applications are used to reinforce science concepts.

### Force, Motion, and Energy

- 3.2 The student will investigate and understand simple machines and their uses. Key concepts include
- purpose and function of simple machines;
  - types of simple machines;
  - compound machines; and
  - examples of simple and compound machines found in the school, home, and work environments.

### Matter

- 3.3 The student will investigate and understand that objects are made of materials that can be described by their physical properties. Key concepts include
- objects are made of one or more materials;
  - physical properties remain the same as the material is changed in visible size; and
  - visible physical changes are identified.

## **Life Processes**

- 3.4 The student will investigate and understand that adaptations allow animals to satisfy life needs and respond to the environment. Key concepts include
- behavioral adaptations; and
  - physical adaptations.

## **Living Systems**

- 3.5 The student will investigate and understand relationships among organisms in aquatic and terrestrial food chains. Key concepts include
- producer, consumer, decomposer;
  - herbivore, carnivore, omnivore; and
  - predator and prey.
- 3.6 The student will investigate and understand that ecosystems support a diversity of plants and animals that share limited resources. Key concepts include
- aquatic ecosystems;
  - terrestrial ecosystems;
  - populations and communities; and
  - the human role in conserving limited resources.

## **Interrelationships in Earth/Space Systems**

- 3.7 The student will investigate and understand the major components of soil, its origin, and its importance to plants and animals including humans. Key concepts include
- soil provides the support and nutrients necessary for plant growth;
  - topsoil is a natural product of subsoil and bedrock;
  - rock, clay, silt, sand, and humus are components of soils; and
  - soil is a natural resource and should be conserved.

## **Earth Patterns, Cycles, and Change**

- 3.8 The student will investigate and understand basic patterns and cycles occurring in nature. Key concepts include
- patterns of natural events such as day and night, seasonal changes, simple phases of the moon, and tides;
  - animal life cycles; and
  - plant life cycles.
- 3.9 The student will investigate and understand the water cycle and its relationship to life on Earth. Key concepts include
- there are many sources of water on Earth;
  - the energy from the sun drives the water cycle;
  - the water cycle involves several processes;
  - water is essential for living things; and
  - water on Earth is limited and needs to be conserved.

## Earth Resources

- 3.10 The student will investigate and understand that natural events and human influences can affect the survival of species. Key concepts include
- a) the interdependency of plants and animals;
  - b) the effects of human activity on the quality of air, water, and habitat;
  - c) the effects of fire, flood, disease, and erosion on organisms; and
  - d) conservation and resource renewal.
- 3.11 The student will investigate and understand different sources of energy. Key concepts include
- a) energy from the sun;
  - b) sources of renewable energy; and
  - c) sources of nonrenewable energy.

## Grade Four

The fourth-grade standards stress the importance of using information, analyzing data, and validating experimental results. Defining variables in experimentation is emphasized, and making simple predictions from picture, bar, and basic line graphs is underscored. Questioning and hypothesizing become more detailed at this level. Students are introduced to basic principles of electricity and to the concept of motion. Students explore basic information about our solar system and investigate the interactions among Earth, the moon, and the sun. Students explore basic plant anatomy, plant adaptations, and investigate relationships among plants and animals and their environments. In examining weather phenomena and conditions, students identify various factors, make predictions based on data, and evaluate the results. The importance of natural resources in Virginia is emphasized.

### Scientific Investigation, Reasoning, and Logic

- 4.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which
- distinctions are made among observations, conclusions, inferences, and predictions;
  - objects or events are classified and arranged according to characteristics or properties;
  - appropriate instruments are selected and used to measure length, mass, volume, and temperature in metric units;
  - appropriate instruments are selected and used to measure elapsed time;
  - predictions and inferences are made, and conclusions are drawn based on data from a variety of sources;
  - independent and dependent variables are identified;
  - constants in an experimental situation are identified;
  - hypotheses are developed as cause and effect relationships;
  - data are collected, recorded, analyzed, and displayed using bar and basic line graphs;
  - numerical data that are contradictory or unusual in experimental results are recognized;
  - data are communicated with simple graphs, pictures, written statements, and numbers;
  - models are constructed to clarify explanations, demonstrate relationships, and solve needs; and
  - current applications are used to reinforce science concepts.

### Force, Motion, and Energy

- 4.2 The student will investigate and understand characteristics and interactions of moving objects. Key concepts include
- motion is described by an object's direction and speed;
  - changes in motion are related to force and mass;
  - friction is a force that opposes motion; and
  - moving objects have kinetic energy.

- 4.3 The student will investigate and understand the characteristics of electricity. Key concepts include
- a) conductors and insulators;
  - b) basic circuits;
  - c) static electricity;
  - d) the ability of electrical energy to be transformed into light and motion, and to produce heat;
  - e) simple electromagnets and magnetism; and
  - f) historical contributions in understanding electricity.

### **Life Processes**

- 4.4 The student will investigate and understand basic plant anatomy and life processes. Key concepts include
- a) the structures of typical plants and the function of each structure;
  - b) processes and structures involved with plant reproduction;
  - c) photosynthesis; and
  - d) adaptations allow plants to satisfy life needs and respond to the environment.

### **Living Systems**

- 4.5 The student will investigate and understand how plants and animals, including humans, in an ecosystem interact with one another and with the nonliving components in the ecosystem. Key concepts include
- a) plant and animal adaptations;
  - b) organization of populations, communities, and ecosystems and how they interrelate;
  - c) flow of energy through food webs;
  - d) habitats and niches;
  - e) changes in an organism's niche at various stages in its life cycle; and
  - f) influences of human activity on ecosystems.

### **Interrelationships in Earth/Space Systems**

- 4.6 The student will investigate and understand how weather conditions and phenomena occur and can be predicted. Key concepts include
- a) weather phenomena;
  - b) weather measurements and meteorological tools; and
  - c) use of weather measurements and weather phenomena to make weather predictions.

### **Earth Patterns, Cycles, and Change**

- 4.7 The student will investigate and understand the organization of the solar system. Key concepts include
- a) the planets in the solar system;
  - b) the order of the planets in the solar system; and
  - c) the relative sizes of the planets.

- 4.8 The student will investigate and understand the relationships among Earth, the moon, and the sun. Key concepts include
- a) the motions of Earth, the moon, and the sun;
  - b) the causes for Earth's seasons;
  - c) the causes for the phases of the moon;
  - d) the relative size, position, age, and makeup of Earth, the moon, and the sun; and
  - e) historical contributions in understanding the Earth-moon-sun system.

## **Earth Resources**

- 4.9 The student will investigate and understand important Virginia natural resources. Key concepts include
- a) watersheds and water resources;
  - b) animals and plants;
  - c) minerals, rocks, ores, and energy sources; and
  - d) forests, soil, and land.

## Grade Five

The fifth-grade standards emphasize the importance of selecting appropriate instruments for measuring and recording observations. The organization, analysis, and application of data continue to be an important focus of classroom inquiry. Science skills from preceding grades, including questioning, using and validating evidence, and systematic experimentation, are reinforced at this level. Students are introduced to more detailed concepts of sound and light and the tools used for studying them. Key concepts of matter, including those about atoms, molecules, elements, and compounds, are studied, and the properties of matter are defined in greater detail. The cellular makeup of organisms and the distinguishing characteristics of groups of organisms are stressed. Students learn about the characteristics of the oceans and Earth's changing surface.

The fifth-grade standards focus on student growth in understanding the nature of science. This scientific view defines the idea that explanations of nature are developed and tested using observation, experimentation, models, evidence, and systematic processes. The nature of science includes the concepts that scientific explanations are based on logical thinking; are subject to rules of evidence; are consistent with observational, inferential, and experimental evidence; are open to rational critique; and are subject to refinement and change with the addition of new scientific evidence. The nature of science includes the concept that science can provide explanations about nature, can predict potential consequences of actions, but cannot be used to answer all questions.

### Scientific Investigation, Reasoning, and Logic

- 5.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which
- a) items such as rocks, minerals, and organisms are identified using various classification keys;
  - b) estimates are made and accurate measurements of length, mass, volume, and temperature are made in metric units using proper tools;
  - c) estimates are made and accurate measurements of elapsed time are made using proper tools;
  - d) hypotheses are formed from testable questions;
  - e) independent and dependent variables are identified;
  - f) constants in an experimental situation are identified;
  - g) data are collected, recorded, analyzed, and communicated using proper graphical representations and metric measurements;
  - h) predictions are made using patterns from data collected, and simple graphical data are generated;
  - i) inferences are made and conclusions are drawn;
  - j) models are constructed to clarify explanations, demonstrate relationships, and solve needs; and
  - k) current applications are used to reinforce science concepts.

## **Force, Motion, and Energy**

- 5.2 The student will investigate and understand how sound is created and transmitted, and how it is used. Key concepts include
- a) compression waves;
  - b) vibration, compression, wavelength, frequency, amplitude;
  - c) the ability of different media (solids, liquids, and gases) to transmit sound; and
  - d) uses and applications of sound waves.
- 5.3 The student will investigate and understand basic characteristics of visible light and how it behaves. Key concepts include
- a) transverse waves;
  - b) the visible spectrum;
  - c) opaque, transparent, and translucent;
  - d) reflection of light from reflective surfaces; and
  - e) refraction of light through water and prisms.

## **Matter**

- 5.4 The student will investigate and understand that matter is anything that has mass and takes up space; and occurs as a solid, liquid, or gas. Key concepts include
- a) distinguishing properties of each phase of matter;
  - b) the effect of temperature on the phases of matter;
  - c) atoms and elements;
  - d) molecules and compounds; and
  - e) mixtures including solutions.

## **Living Systems**

- 5.5 The student will investigate and understand that organisms are made of one or more cells and have distinguishing characteristics that play a vital role in the organism's ability to survive and thrive in its environment. Key concepts include
- a) basic cell structures and functions;
  - b) classification of organisms using physical characteristics, body structures, and behavior of the organism; and
  - c) traits of organisms that allow them to survive in their environment.

## **Interrelationships in Earth/Space Systems**

- 5.6 The student will investigate and understand characteristics of the ocean environment. Key concepts include
- a) geological characteristics;
  - b) physical characteristics; and
  - c) ecological characteristics.



## **Earth Patterns, Cycles, and Change**

- 5.7 The student will investigate and understand how Earth's surface is constantly changing. Key concepts include
- a) identification of rock types;
  - b) the rock cycle and how transformations between rocks occur;
  - c) Earth history and fossil evidence;
  - d) the basic structure of Earth's interior;
  - e) changes in Earth's crust due to plate tectonics;
  - f) weathering, erosion, and deposition; and
  - g) human impact.

# Grade Six

The sixth-grade standards continue to emphasize data analysis and experimentation. Methods are studied for testing the validity of predictions and conclusions. Scientific methodology, focusing on precision in stating hypotheses and defining dependent and independent variables, is strongly reinforced. The concept of change is explored through the study of transformations of energy and matter. The standards present an integrated focus on the role of the sun's energy in Earth's systems, on water in the environment, on air and atmosphere, and on basic chemistry concepts. A more detailed understanding of the solar system and space exploration becomes a focus of instruction. Natural resource management, its relation to public policy, and cost/benefit tradeoffs in conservation policies are introduced.

The sixth-grade standards continue to focus on student growth in understanding the nature of science. This scientific view defines the idea that explanations of nature are developed and tested using observation, experimentation, models, evidence, and systematic processes. The nature of science includes the concepts that scientific explanations are based on logical thinking; are subject to rules of evidence; are consistent with observational, inferential, and experimental evidence; are open to rational critique; and are subject to refinement and change with the addition of new scientific evidence. The nature of science includes the concept that science can provide explanations about nature and can predict potential consequences of actions, but cannot be used to answer all questions.

## Scientific Investigation, Reasoning, and Logic

- 6.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which
- observations are made involving fine discrimination between similar objects and organisms;
  - precise and approximate measurements are recorded;
  - scale models are used to estimate distance, volume, and quantity;
  - hypotheses are stated in ways that identify the independent and dependent variables;
  - a method is devised to test the validity of predictions and inferences;
  - one variable is manipulated over time, using many repeated trials;
  - data are collected, recorded, analyzed, and reported using metric measurements and tools;
  - data are analyzed and communicated through graphical representation;
  - models and simulations are designed and used to illustrate and explain phenomena and systems; and
  - current applications are used to reinforce science concepts.

## Force, Motion, and Energy

- 6.2 The student will investigate and understand basic sources of energy, their origins, transformations, and uses. Key concepts include
- potential and kinetic energy;
  - the role of the sun in the formation of most energy sources on Earth;
  - nonrenewable energy sources;
  - renewable energy sources; and
  - energy transformations.

- 6.3 The student will investigate and understand the role of solar energy in driving most natural processes within the atmosphere, the hydrosphere, and on Earth's surface. Key concepts include
- a) Earth's energy budget;
  - b) the role of radiation and convection in the distribution of energy;
  - c) the motion of the atmosphere and the oceans;
  - d) cloud formation; and
  - e) the role of thermal energy in weather-related phenomena including thunderstorms and hurricanes.

## **Matter**

- 6.4 The student will investigate and understand that all matter is made up of atoms. Key concepts include
- a) atoms consist of particles, including electrons, protons, and neutrons;
  - b) atoms of a particular element are alike but are different from atoms of other elements;
  - c) elements may be represented by chemical symbols;
  - d) two or more atoms interact to form new substances, which are held together by electrical forces (bonds);
  - e) compounds may be represented by chemical formulas;
  - f) chemical equations can be used to model chemical changes; and
  - g) a limited number of elements comprise the largest portion of the solid Earth, living matter, the oceans, and the atmosphere.
- 6.5 The student will investigate and understand the unique properties and characteristics of water and its roles in the natural and human-made environment. Key concepts include
- a) water as the universal solvent;
  - b) the properties of water in all three phases;
  - c) the action of water in physical and chemical weathering;
  - d) the ability of large bodies of water to store thermal energy and moderate climate;
  - e) the importance of water for agriculture, power generation, and public health; and
  - f) the importance of protecting and maintaining water resources.
- 6.6 The student will investigate and understand the properties of air and the structure and dynamics of Earth's atmosphere. Key concepts include
- a) air as a mixture of gaseous elements and compounds;
  - b) pressure, temperature, and humidity;
  - c) atmospheric changes with altitude;
  - d) natural and human-caused changes to the atmosphere and the importance of protecting and maintaining air quality;
  - e) the relationship of atmospheric measures and weather conditions; and
  - f) basic information from weather maps, including fronts, systems, and basic measurements.

## Living Systems

- 6.7 The student will investigate and understand the natural processes and human interactions that affect watershed systems. Key concepts include
- a) the health of ecosystems and the abiotic factors of a watershed;
  - b) the location and structure of Virginia's regional watershed systems;
  - c) divides, tributaries, river systems, and river and stream processes;
  - d) wetlands;
  - e) estuaries;
  - f) major conservation, health, and safety issues associated with watersheds; and
  - g) water monitoring and analysis using field equipment including hand-held technology.

## Interrelationships in Earth/Space Systems

- 6.8 The student will investigate and understand the organization of the solar system and the interactions among the various bodies that comprise it. Key concepts include
- a) the sun, moon, Earth, other planets and their moons, dwarf planets, meteors, asteroids, and comets;
  - b) relative size of and distance between planets;
  - c) the role of gravity;
  - d) revolution and rotation;
  - e) the mechanics of day and night and the phases of the moon;
  - f) the unique properties of Earth as a planet;
  - g) the relationship of Earth's tilt and the seasons;
  - h) the cause of tides; and
  - i) the history and technology of space exploration.

## Earth Resources

- 6.9 The student will investigate and understand public policy decisions relating to the environment. Key concepts include
- a) management of renewable resources;
  - b) management of nonrenewable resources;
  - c) the mitigation of land-use and environmental hazards through preventive measures; and
  - d) cost/benefit tradeoffs in conservation policies.

# Life Science

The Life Science standards emphasize a more complex understanding of change, cycles, patterns, and relationships in the living world. Students build on basic principles related to these concepts by exploring the cellular organization and the classification of organisms; the dynamic relationships among organisms, populations, communities, and ecosystems; and change as a result of the transmission of genetic information from generation to generation. Inquiry skills at this level include organization and mathematical analysis of data, manipulation of variables in experiments, and identification of sources of experimental error. Metric units (SI – International System of Units) are expected to be used as the primary unit of measurement to gather and report data at this level.

The Life Science standards continue to focus on student growth in understanding the nature of science. This scientific view defines the idea that explanations of nature are developed and tested using observation, experimentation, models, evidence, and systematic processes. The nature of science includes the concepts that scientific explanations are based on logical thinking; are subject to rules of evidence; are consistent with observational, inferential, and experimental evidence; are open to rational critique; and are subject to refinement and change with the addition of new scientific evidence. The nature of science includes the concept that science can provide explanations about nature and can predict potential consequences of actions, but cannot be used to answer all questions.

- LS.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which
- data are organized into tables showing repeated trials and means;
  - a classification system is developed based on multiple attributes;
  - triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, and probeware are used to gather data;
  - models and simulations are constructed and used to illustrate and explain phenomena;
  - sources of experimental error are identified;
  - dependent variables, independent variables, and constants are identified;
  - variables are controlled to test hypotheses, and trials are repeated;
  - data are organized, communicated through graphical representation, interpreted, and used to make predictions;
  - patterns are identified in data and are interpreted and evaluated; and
  - current applications are used to reinforce life science concepts.
- LS.2 The student will investigate and understand that all living things are composed of cells. Key concepts include
- cell structure and organelles;
  - similarities and differences between plant and animal cells;
  - development of cell theory; and
  - cell division.
- LS.3 The student will investigate and understand that living things show patterns of cellular organization. Key concepts include
- cells, tissues, organs, and systems; and
  - patterns of cellular organization and their relationship to life processes in living things.

- LS.4 The student will investigate and understand how organisms can be classified. Key concepts include
- a) the distinguishing characteristics of domains of organisms;
  - b) the distinguishing characteristics of kingdoms of organisms;
  - c) the distinguishing characteristics of major animal phyla and plant divisions; and
  - d) the characteristics that define a species.
- LS.5 The student will investigate and understand the basic physical and chemical processes of photosynthesis and its importance to plant and animal life. Key concepts include
- a) energy transfer between sunlight and chlorophyll;
  - b) transformation of water and carbon dioxide into sugar and oxygen; and
  - c) photosynthesis as the foundation of virtually all food webs.
- LS.6 The student will investigate and understand that organisms within an ecosystem are dependent on one another and on nonliving components of the environment. Key concepts include
- a) the carbon, water, and nitrogen cycles;
  - b) interactions resulting in a flow of energy and matter throughout the system;
  - c) complex relationships within terrestrial, freshwater, and marine ecosystems; and
  - d) energy flow in food webs and energy pyramids.
- LS.7 The student will investigate and understand that interactions exist among members of a population. Key concepts include
- a) competition, cooperation, social hierarchy, territorial imperative; and
  - b) influence of behavior on a population.
- LS.8 The student will investigate and understand interactions among populations in a biological community. Key concepts include
- a) the relationships among producers, consumers, and decomposers in food webs;
  - b) the relationship between predators and prey;
  - c) competition and cooperation;
  - d) symbiotic relationships; and
  - e) niches.
- LS.9 The student will investigate and understand how organisms adapt to biotic and abiotic factors in an ecosystem. Key concepts include
- a) differences between ecosystems and biomes;
  - b) characteristics of land, marine, and freshwater ecosystems; and
  - c) adaptations that enable organisms to survive within a specific ecosystem.
- LS.10 The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic, change over time, and respond to daily, seasonal, and long-term changes in their environment. Key concepts include
- a) phototropism, hibernation, and dormancy;
  - b) factors that increase or decrease population size; and
  - c) eutrophication, climate changes, and catastrophic disturbances.

- LS.11 The student will investigate and understand the relationships between ecosystem dynamics and human activity. Key concepts include
- a) food production and harvest;
  - b) change in habitat size, quality, or structure;
  - c) change in species competition;
  - d) population disturbances and factors that threaten or enhance species survival; and
  - e) environmental issues.
- LS.12 The student will investigate and understand that organisms reproduce and transmit genetic information to new generations. Key concepts include
- a) the structure and role of DNA;
  - b) the function of genes and chromosomes;
  - c) genotypes and phenotypes;
  - d) characteristics that can and cannot be inherited;
  - e) genetic engineering and its applications; and
  - f) historical contributions and significance of discoveries related to genetics.
- LS.13 The student will investigate and understand that populations of organisms change over time. Key concepts include
- a) the relationships of mutation, adaptation, natural selection, and extinction;
  - b) evidence of evolution of different species in the fossil record; and
  - c) how environmental influences, as well as genetic variation, can lead to diversity of organisms.

# Physical Science

The Physical Science standards continue to build on skills of systematic investigation with a clear focus on variables and repeated trials. Validating conclusions using evidence and data becomes increasingly important at this level. Students will plan and conduct research involving both classroom experimentation and literature reviews from written and electronic resources. Research methods and skills highlight practical problems and questions. Students will share their work using written reports and other presentations and will continue to use metric units (SI – International System of Units) as the primary unit of measurement for gathering and reporting data.

The Physical Science standards stress an in-depth understanding of the nature and structure of matter and the characteristics of energy. The standards place considerable emphasis on the technological application of physical science principles. Major areas covered by the standards include the organization and use of the periodic table; physical and chemical changes; nuclear reactions; temperature and heat; sound; light; electricity and magnetism; and work, force, and motion.

The Physical Science standards continue to focus on student growth in understanding the nature of science. This scientific view defines the idea that explanations of nature are developed and tested using observation, experimentation, models, evidence, and systematic processes. The nature of science includes the concepts that scientific explanations are based on logical thinking; are subject to rules of evidence; are consistent with observational, inferential, and experimental evidence; are open to rational critique; and are subject to refinement and change with the addition of new scientific evidence. The nature of science includes the concept that science can provide explanations about nature and can predict potential consequences of actions, but cannot be used to answer all questions.

- PS.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which
- a) chemicals and equipment are used safely;
  - b) length, mass, volume, density, temperature, weight, and force are accurately measured;
  - c) conversions are made among metric units, applying appropriate prefixes;
  - d) triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, probeware, and spring scales are used to gather data;
  - e) numbers are expressed in scientific notation where appropriate;
  - f) independent and dependent variables, constants, controls, and repeated trials are identified;
  - g) data tables showing the independent and dependent variables, derived quantities, and the number of trials are constructed and interpreted;
  - h) data tables for descriptive statistics showing specific measures of central tendency, the range of the data set, and the number of repeated trials are constructed and interpreted;
  - i) frequency distributions, scatterplots, line plots, and histograms are constructed and interpreted;
  - j) valid conclusions are made after analyzing data;
  - k) research methods are used to investigate practical problems and questions;
  - l) experimental results are presented in appropriate written form;
  - m) models and simulations are constructed and used to illustrate and explain phenomena; and
  - n) current applications of physical science concepts are used.



- PS.2 The student will investigate and understand the nature of matter. Key concepts include
- the particle theory of matter;
  - elements, compounds, mixtures, acids, bases, and salts;
  - solids, liquids, and gases;
  - physical properties;
  - chemical properties; and
  - characteristics of types of matter based on physical and chemical properties.
- PS.3 The student will investigate and understand the modern and historical models of atomic structure. Key concepts include
- the contributions of Dalton, Thomson, Rutherford, and Bohr in understanding the atom; and
  - the modern model of atomic structure.
- PS.4 The student will investigate and understand the organization and use of the periodic table of elements to obtain information. Key concepts include
- symbols, atomic numbers, atomic mass, chemical families (groups), and periods;
  - classification of elements as metals, metalloids, and nonmetals; and
  - formation of compounds through ionic and covalent bonding.
- PS.5 The student will investigate and understand changes in matter and the relationship of these changes to the Law of Conservation of Matter and Energy. Key concepts include
- physical changes;
  - chemical changes; and
  - nuclear reactions.
- PS.6 The student will investigate and understand forms of energy and how energy is transferred and transformed. Key concepts include
- potential and kinetic energy; and
  - mechanical, chemical, electrical, thermal, radiant, and nuclear energy.
- PS.7 The student will investigate and understand temperature scales, heat, and thermal energy transfer. Key concepts include
- Celsius and Kelvin temperature scales and absolute zero;
  - phase change, freezing point, melting point, boiling point, vaporization, and condensation;
  - conduction, convection, and radiation; and
  - applications of thermal energy transfer.
- PS.8 The student will investigate and understand the characteristics of sound waves. Key concepts include
- wavelength, frequency, speed, amplitude, rarefaction, and compression;
  - resonance;
  - the nature of compression waves; and
  - technological applications of sound.

- PS.9 The student will investigate and understand the characteristics of transverse waves. Key concepts include
- wavelength, frequency, speed, amplitude, crest, and trough;
  - the wave behavior of light;
  - images formed by lenses and mirrors;
  - the electromagnetic spectrum; and
  - technological applications of light.
- PS.10 The student will investigate and understand the scientific principles of work, force, and motion. Key concepts include
- speed, velocity, and acceleration;
  - Newton's laws of motion;
  - work, force, mechanical advantage, efficiency, and power; and
  - technological applications of work, force, and motion.
- PS.11 The student will investigate and understand basic principles of electricity and magnetism. Key concepts include
- static electricity, current electricity, and circuits;
  - relationship between a magnetic field and an electric current;
  - electromagnets, motors, and generators and their uses; and
  - conductors, semiconductors, and insulators.

# Earth Science

The Earth Science standards connect the study of Earth's composition, structure, processes, and history; its atmosphere, fresh water, and oceans; and its environment in space. The standards emphasize historical contributions in the development of scientific thought about Earth and space. The standards stress the interpretation of maps, charts, tables, and profiles; the use of technology to collect, analyze, and report data; and the utilization of science skills in systematic investigation. Problem solving and decision making are an integral part of the standards, especially as they relate to the costs and benefits of utilizing Earth's resources. Major topics of study include plate tectonics, the rock cycle, Earth history, the oceans, the atmosphere, weather and climate, and the solar system and universe.

The Earth Science standards continue to focus on student growth in understanding the nature of science. This scientific view defines the idea that explanations of nature are developed and tested using observation, experimentation, models, evidence, and systematic processes. The nature of science includes the concepts that scientific explanations are based on logical thinking; are subject to rules of evidence; are consistent with observational, inferential, and experimental evidence; are open to rational critique; and are subject to refinement and change with the addition of new scientific evidence. The nature of science includes the concept that science can provide explanations about nature and can predict potential consequences of actions, but cannot be used to answer all questions.

- ES.1 The student will plan and conduct investigations in which
- volume, area, mass, elapsed time, direction, temperature, pressure, distance, density, and changes in elevation/depth are calculated utilizing the most appropriate tools;
  - technologies, including computers, probeware, and geospatial technologies, are used to collect, analyze, and report data and to demonstrate concepts and simulate experimental conditions;
  - scales, diagrams, charts, graphs, tables, imagery, models, and profiles are constructed and interpreted;
  - maps and globes are read and interpreted, including location by latitude and longitude;
  - variables are manipulated with repeated trials; and
  - current applications are used to reinforce Earth science concepts.
- ES.2 The student will demonstrate an understanding of the nature of science and scientific reasoning and logic. Key concepts include
- science explains and predicts the interactions and dynamics of complex Earth systems;
  - evidence is required to evaluate hypotheses and explanations;
  - observation and logic are essential for reaching a conclusion; and
  - evidence is evaluated for scientific theories.
- ES.3 The student will investigate and understand the characteristics of Earth and the solar system. Key concepts include
- position of Earth in the solar system;
  - sun-Earth-moon relationships; (seasons, tides, and eclipses);
  - characteristics of the sun, planets and their moons, comets, meteors, and asteroids; and
  - the history and contributions of space exploration.

- ES.4 The student will investigate and understand how to identify major rock-forming and ore minerals based on physical and chemical properties. Key concepts include
- hardness, color and streak, luster, cleavage, fracture, and unique properties; and
  - uses of minerals.
- ES.5 The student will investigate and understand the rock cycle as it relates to the origin and transformation of rock types and how to identify common rock types based on mineral composition and textures. Key concepts include
- igneous rocks;
  - sedimentary rocks; and
  - metamorphic rocks.
- ES.6 The student will investigate and understand the differences between renewable and nonrenewable resources. Key concepts include
- fossil fuels, minerals, rocks, water, and vegetation;
  - advantages and disadvantages of various energy sources;
  - resources found in Virginia; and
  - environmental costs and benefits.
- ES.7 The student will investigate and understand geologic processes including plate tectonics. Key concepts include
- geologic processes and their resulting features; and
  - tectonic processes.
- ES.8 The student will investigate and understand how freshwater resources are influenced by geologic processes and the activities of humans. Key concepts include
- processes of soil development;
  - development of karst topography;
  - relationships between groundwater zones, including saturated and unsaturated zones, and the water table;
  - identification of sources of fresh water including rivers, springs, and aquifers, with reference to the hydrologic cycle;
  - dependence on freshwater resources and the effects of human usage on water quality; and
  - identification of the major watershed systems in Virginia, including the Chesapeake Bay and its tributaries.
- ES.9 The student will investigate and understand that many aspects of the history and evolution of Earth and life can be inferred by studying rocks and fossils. Key concepts include
- traces and remains of ancient, often extinct, life are preserved by various means in many sedimentary rocks;
  - superposition, cross-cutting relationships, index fossils, and radioactive decay are methods of dating bodies of rock;
  - absolute and relative dating have different applications but can be used together to determine the age of rocks and structures; and
  - rocks and fossils from many different geologic periods and epochs are found in Virginia.

- ES.10 The student will investigate and understand that oceans are complex, interactive physical, chemical, and biological systems and are subject to long- and short-term variations. Key concepts include
- a) physical and chemical changes related to tides, waves, currents, sea level and ice cap variations, upwelling, and salinity variations;
  - b) importance of environmental and geologic implications;
  - c) systems interactions;
  - d) features of the sea floor as reflections of tectonic processes; and
  - e) economic and public policy issues concerning the oceans and the coastal zone including the Chesapeake Bay.
- ES.11 The student will investigate and understand the origin and evolution of the atmosphere and the interrelationship of geologic processes, biologic processes, and human activities on its composition and dynamics. Key concepts include
- a) scientific evidence for atmospheric composition changes over geologic time;
  - b) current theories related to the effects of early life on the chemical makeup of the atmosphere;
  - c) atmospheric regulation mechanisms including the effects of density differences and energy transfer; and
  - d) potential changes to the atmosphere and climate due to human, biologic, and geologic activity.
- ES.12 The student will investigate and understand that energy transfer between the sun and Earth and its atmosphere drives weather and climate on Earth. Key concepts include
- a) observation and collection of weather data;
  - b) prediction of weather patterns;
  - c) severe weather occurrences, such as tornadoes, hurricanes, and major storms; and
  - d) weather phenomena and the factors that affect climate including radiation, conduction, and convection.
- ES.13 The student will investigate and understand scientific concepts related to the origin and evolution of the universe. Key concepts include
- a) cosmology including the Big Bang theory; and
  - b) the origin and evolution of stars, star systems, and galaxies.

# Biology

The Biology standards are designed to provide students with a detailed understanding of living systems. Emphasis continues to be placed on the skills necessary to examine alternative scientific explanations, actively conduct controlled experiments, analyze and communicate information, and gather and use information in scientific literature. The history of biological thought and the evidence that supports it are explored, providing the foundation for investigating biochemical life processes, cellular organization, mechanisms of inheritance, dynamic relationships among organisms, and the change in organisms through time. The importance of scientific research that validates or challenges ideas is emphasized at this level. All students are expected to achieve the content of the biology standards.

The Biology standards continue to focus on student growth in understanding the nature of science. This scientific view defines the idea that explanations of nature are developed and tested using observation, experimentation, models, evidence, and systematic processes. The nature of science includes the concepts that scientific explanations are based on logical thinking; are subject to rules of evidence; are consistent with observational, inferential, and experimental evidence; are open to rational critique; and are subject to refinement and change with the addition of new scientific evidence. The nature of science includes the concept that science can provide explanations about nature and can predict potential consequences of actions, but cannot be used to answer all questions.

- BIO.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which
- observations of living organisms are recorded in the lab and in the field;
  - hypotheses are formulated based on direct observations and information from scientific literature;
  - variables are defined and investigations are designed to test hypotheses;
  - graphing and arithmetic calculations are used as tools in data analysis;
  - conclusions are formed based on recorded quantitative and qualitative data;
  - sources of error inherent in experimental design are identified and discussed;
  - validity of data is determined;
  - chemicals and equipment are used in a safe manner;
  - appropriate technology including computers, graphing calculators, and probeware, is used for gathering and analyzing data, communicating results, modeling concepts, and simulating experimental conditions;
  - research utilizes scientific literature;
  - differentiation is made between a scientific hypothesis, theory, and law;
  - alternative scientific explanations and models are recognized and analyzed; and
  - current applications of biological concepts are used.
- BIO.2 The student will investigate and understand the chemical and biochemical principles essential for life. Key concepts include
- water chemistry and its impact on life processes;
  - the structure and function of macromolecules;
  - the nature of enzymes; and
  - the capture, storage, transformation, and flow of energy through the processes of photosynthesis and respiration.

- BIO.3 The student will investigate and understand relationships between cell structure and function. Key concepts include
- evidence supporting the cell theory;
  - characteristics of prokaryotic and eukaryotic cells;
  - similarities between the activities of the organelles in a single cell and a whole organism;
  - the cell membrane model; and
  - the impact of surface area to volume ratio on cell division, material transport, and other life processes.
- BIO.4 The student will investigate and understand life functions of Archaea, Bacteria and Eukarya. Key concepts include
- comparison of their metabolic activities;
  - maintenance of homeostasis;
  - how the structures and functions vary among and within the Eukarya kingdoms of protists, fungi, plants, and animals, including humans;
  - human health issues, human anatomy, and body systems;
  - how viruses compare with organisms; and
  - evidence supporting the germ theory of infectious disease.
- BIO.5 The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include
- cell growth and division;
  - gamete formation;
  - cell specialization;
  - prediction of inheritance of traits based on the Mendelian laws of heredity;
  - historical development of the structural model of DNA;
  - genetic variation;
  - the structure, function, and replication of nucleic acids;
  - events involved in the construction of proteins;
  - use, limitations, and misuse of genetic information; and
  - exploration of the impact of DNA technologies.
- BIO.6 The student will investigate and understand bases for modern classification systems. Key concepts include
- structural similarities among organisms;
  - fossil record interpretation;
  - comparison of developmental stages in different organisms;
  - examination of biochemical similarities and differences among organisms; and
  - systems of classification that are adaptable to new scientific discoveries.
- BIO.7 The student will investigate and understand how populations change through time. Key concepts include
- evidence found in fossil records;
  - how genetic variation, reproductive strategies, and environmental pressures impact the survival of populations;
  - how natural selection leads to adaptations;
  - emergence of new species; and
  - scientific evidence and explanations for biological evolution.

- BIO.8 The student will investigate and understand dynamic equilibria within populations, communities, and ecosystems. Key concepts include
- a) interactions within and among populations including carrying capacities, limiting factors, and growth curves;
  - b) nutrient cycling with energy flow through ecosystems;
  - c) succession patterns in ecosystems;
  - d) the effects of natural events and human activities on ecosystems; and
  - e) analysis of the flora, fauna, and microorganisms of Virginia ecosystems.



# Chemistry

The Chemistry standards are designed to provide students with a detailed understanding of the interaction of matter and energy. This interaction is investigated through the use of laboratory techniques, manipulation of chemical quantities, and problem-solving applications. Scientific methodology is employed in experimental and analytical investigations, and concepts are illustrated with current practical applications that should include examples from environmental, nuclear, organic, and biochemistry content areas.

Technology, including graphing calculators, computers, and probeware, are employed where feasible. Students will understand and use safety precautions with chemicals and equipment. The standards emphasize qualitative and quantitative study of substances and the changes that occur in them. In meeting the chemistry standards, students will be encouraged to share their ideas, use the language of chemistry, discuss problem-solving techniques, and communicate effectively.

The Chemistry standards continue to focus on student growth in understanding the nature of science. This scientific view defines the idea that explanations of nature are developed and tested using observation, experimentation, models, evidence, and systematic processes. The nature of science includes the concepts that scientific explanations are based on logical thinking; are subject to rules of evidence; are consistent with observational, inferential, and experimental evidence; are open to rational critique; and are subject to refinement and change with the addition of new scientific evidence. The nature of science includes the concept that science can provide explanations about nature and can predict potential consequences of actions, but cannot be used to answer all questions.

- CH.1 The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include
- a) designated laboratory techniques;
  - b) safe use of chemicals and equipment;
  - c) proper response to emergency situations;
  - d) manipulation of multiple variables, using repeated trials;
  - e) accurate recording, organization, and analysis of data through repeated trials;
  - f) mathematical and procedural error analysis;
  - g) mathematical manipulations including SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, and dimensional analysis;
  - h) use of appropriate technology including computers, graphing calculators, and probeware, for gathering data, communicating results, and using simulations to model concepts;
  - i) construction and defense of a scientific viewpoint; and
  - j) the use of current applications to reinforce chemistry concepts.

- CH.2 The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of
- average atomic mass, mass number, and atomic number;
  - isotopes, half lives, and radioactive decay;
  - mass and charge characteristics of subatomic particles;
  - families or groups;
  - periods;
  - trends including atomic radii, electronegativity, shielding effect, and ionization energy;
  - electron configurations, valence electrons, and oxidation numbers;
  - chemical and physical properties; and
  - historical and quantum models.
- CH.3 The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include
- nomenclature;
  - balancing chemical equations;
  - writing chemical formulas;
  - bonding types;
  - reaction types; and
  - reaction rates, kinetics, and equilibrium.
- CH.4 The student will investigate and understand that chemical quantities are based on molar relationships. Key concepts include
- Avogadro's principle and molar volume;
  - stoichiometric relationships;
  - solution concentrations; and
  - acid/base theory; strong electrolytes, weak electrolytes, and nonelectrolytes; dissociation and ionization; pH and pOH; and the titration process.
- CH.5 The student will investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles. Key concepts include
- pressure, temperature, and volume;
  - partial pressure and gas laws;
  - vapor pressure;
  - phase changes;
  - molar heats of fusion and vaporization;
  - specific heat capacity; and
  - colligative properties.
- CH.6 The student will investigate and understand how basic chemical properties relate to organic chemistry and biochemistry. Key concepts include
- unique properties of carbon that allow multi-carbon compounds; and
  - uses in pharmaceuticals and genetics, petrochemicals, plastics, and food.

# Physics

The Physics standards emphasize a more complex understanding of experimentation, the analysis of data, and the use of reasoning and logic to evaluate evidence. The use of mathematics, including algebra and trigonometry, is important, but conceptual understanding of physical systems remains a primary concern. Students build on basic physical science principles by exploring in-depth the nature and characteristics of energy and its dynamic interaction with matter. Key areas covered by the standards include force and motion, energy transformations, wave phenomena and the electromagnetic spectrum, electricity, fields, and non-Newtonian physics. The standards stress the practical application of physics in other areas of science, technology, engineering, and mathematics. The effects of physics on our world are investigated through the study of critical, contemporary global topics.

The Physics standards continue to focus on student growth in understanding the nature of science. This scientific view defines the idea that explanations of nature are developed and tested using observation, experimentation, models, evidence, and systematic processes. The nature of science includes the concepts that scientific explanations are based on logical thinking; are subject to rules of evidence; are consistent with observational, inferential, and experimental evidence; are open to rational critique; and are subject to refinement and change with the addition of new scientific evidence. The nature of science includes the concept that science can provide explanations about nature and can predict potential consequences of actions, but cannot be used to answer all questions.

- PH.1 The student will plan and conduct investigations using experimental design and product design processes. Key concepts include
- a) the components of a system are defined;
  - b) instruments are selected and used to extend observations and measurements;
  - c) information is recorded and presented in an organized format;
  - d) the limitations of the experimental apparatus and design are recognized;
  - e) the limitations of measured quantities are recognized through the appropriate use of significant figures or error ranges;
  - f) models and simulations are used to visualize and explain phenomena, to make predictions from hypotheses, and to interpret data; and
  - g) appropriate technology, including computers, graphing calculators, and probeware, is used for gathering and analyzing data and communicating results.
- PH.2 The student will investigate and understand how to analyze and interpret data. Key concepts include
- a) a description of a physical problem is translated into a mathematical statement in order to find a solution;
  - b) relationships between physical quantities are determined using the shape of a curve passing through experimentally obtained data;
  - c) the slope of a linear relationship is calculated and includes appropriate units;
  - d) interpolated, extrapolated, and analyzed trends are used to make predictions; and
  - e) situations with vector quantities are analyzed utilizing trigonometric or graphical methods.

- PH.3 The student will investigate and demonstrate an understanding of the nature of science, scientific reasoning, and logic. Key concepts include
- analysis of scientific sources to develop and refine research hypotheses;
  - analysis of how science explains and predicts relationships;
  - evaluation of evidence for scientific theories;
  - examination of how new discoveries result in modification of existing theories or establishment of new paradigms; and
  - construction and defense of a scientific viewpoint.
- PH.4 The student will investigate and understand how applications of physics affect the world. Key concepts include
- examples from the real world; and
  - exploration of the roles and contributions of science and technology.
- PH.5 The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. Key concepts include
- linear motion;
  - uniform circular motion;
  - projectile motion;
  - Newton's laws of motion;
  - gravitation;
  - planetary motion; and
  - work, power, and energy.
- PH.6 The student will investigate and understand that quantities including mass, energy, momentum, and charge are conserved. Key concepts include
- kinetic and potential energy;
  - elastic and inelastic collisions; and
  - mass/energy equivalence.
- PH.7 The student will investigate and understand that energy can be transferred and transformed to provide usable work. Key concepts include
- transfer and storage of energy among systems including mechanical, thermal, gravitational, electromagnetic, chemical, and nuclear systems; and
  - efficiency of systems.
- PH.8 The student will investigate and understand wave phenomena. Key concepts include
- wave characteristics;
  - fundamental wave processes; and
  - light and sound in terms of wave models.
- PH.9 The student will investigate and understand that different frequencies and wavelengths in the electromagnetic spectrum are phenomena ranging from radio waves through visible light to gamma radiation. Key concepts include
- the properties, behaviors, and relative size of radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays;
  - wave/particle dual nature of light; and
  - current applications based on the respective wavelengths.

- PH.10 The student will investigate and understand how to use the field concept to describe the effects of gravitational, electric, and magnetic forces. Key concepts include
- a) inverse square laws (Newton's law of universal gravitation and Coulomb's law); and
  - b) technological applications.
- PH.11 The student will investigate and understand how to diagram, construct, and analyze basic electrical circuits and explain the function of various circuit components. Key concepts include
- a) Ohm's law;
  - b) series, parallel, and combined circuits;
  - c) electrical power; and
  - d) alternating and direct currents.
- PH.12 The student will investigate and understand that extremely large and extremely small quantities are not necessarily described by the same laws as those studied in Newtonian physics. Key concepts may include
- a) wave/particle duality;
  - b) wave properties of matter;
  - c) matter/energy equivalence;
  - d) quantum mechanics and uncertainty;
  - e) relativity;
  - f) nuclear physics;
  - g) solid state physics;
  - h) nanotechnology;
  - i) superconductivity; and
  - j) radioactivity.