2025 Expanded High School Science *Standards of Learning* for Virginia Public Schools

Insert Date

Board of Education
Commonwealth of Virginia

2025 Expanded High School Science *Standards of Learning* for Virginia Public Schools

Adopted on Insert Date 2025 by the
Board of Education

Superintendent of Public Instruction
Emily Anne Gullickson

P. O. Box 2120
Richmond, Virginia 23218-2120
[Virginia Department of Education]

Statement of Non-Discrimination
The Virginia Department of Education does not discriminate on the basis of race, sex, color, national origin, religion, sexual orientation, gender identity, age, political affiliation, or against otherwise qualified persons with disabilities. The policy permits appropriate employment preferences for veterans and specifically prohibits discrimination against veterans.

Table of Contents

Science *Standards of Learning* Introduction

The goal of the 2025 Expanded High School Science *Standards of Learning* is to provide a foundation in scientific concepts and skills that will prepare students to pursue STEM career fields as well as participate in society as scientifically literate citizens. Students will be equipped with the ability to analyze data to solve problems and think analytically, communicate effectively, and collaborate with diverse groups in their community, workplace, and postsecondary education. As students progress through the school years, they are active learners in developing and applying the Scientific and Engineering Practices as they engage with increasingly complex science concepts. The 2025 Expanded High School Science *Standards of Learning* reflect the commitment to provide clear and specific standards for teachers.

This introduction provides a brief overview of the following context around these standards.

1. Guiding Principles
2. Standards vs. Curriculum
3. Investigate and Understand
4. K-12 Safety

Guiding Principles

The 2025 Expanded High School Science *Standards of Learning* indicate the scientific concepts and practices that will ensure that every Virginia student graduates high school with the science knowledge and skills needed to be ready for enrollment in a postsecondary program, enlistment in the military, or employment in an in-demand field, as described in the 3E Framework. The following principles guided the development of the Standards:

1. Reflects accurate and current science content.

Technological advancements lead to a deeper understanding of natural phenomena and may result in new scientific discoveries. Accurate standards based on current understanding of science concepts and practices allow students to appreciate the dynamic nature of scientific inquiry and cultivate informed graduates who can make evidence-based decisions and contribute meaningfully to society. The 2025 Expanded High School Science *Standards of Learning* were developed to be best in class and reflect current scientific knowledge.

2. Prepare students for enrollment, enlistment, or employment.

A foundation in science concepts and practices, including the ability to analyze data, construct and critique explanations, and communicate information are critical skills needed for enrollment, enlistment, or employment. Scientifically literate citizens are essential for contributing to a skilled workforce and for making informed decisions that affect their lives, their communities, and the world.

3. Incorporates Virginia context to support science instruction.

Personal interest and experience are critical to helping students learn science. The 2025 Expanded High School Science *Standards of Learning* provide opportunities for teachers to use Virginia phenomena and their local context to engage students. This connection to the local community, and how it fits in a global context, prepares students for their postsecondary goals of enrollment, enlistment, or enrollment.

4. Conveys high academic expectations for all students.

For the first time, teachers will have standards for these courses. These standards ensure equal and rigorous expectations and opportunities for students across the Commonwealth.

Standards vs. Curriculum

The 2025 Expanded High School Science *Standards of Learning* define the concepts and skills that are to be taught in each year of K-12 science instruction. Divisions can adopt High Quality Instructional Materials (HQIM) to assist with curriculum and instruction. The Science *Standards of Learning* indicate the expectations of students to demonstrate mastery of grade level scientific concepts. School divisions determine the order that these standards are to be taught.

Investigate and Understand

The standards in the 2025 Expanded High School Science *Standards of Learning* begin with the phrase “The student will investigate and understand.” This phrase communicates the wide range of science knowledge, skills, and practices required to effectively make meaning of the natural world.

“Investigate” refers to the student application of the Scientific and Engineering Practices. Science utilizes observation and experimentation along with existing scientific knowledge, mathematics, and engineering technologies to answer questions about the natural world. Engineering employs existing scientific knowledge, mathematics, and technology to create, design, and develop new devices, objects, or technology to meet the needs of society. By utilizing both scientific and engineering practices in the science classroom, students develop a deeper understanding and competence with techniques at the heart of each discipline. These practices are integrated and scaffold K-12 and should be embedded in instruction throughout the year. The Scientific and Engineering Practices are:

- asking questions and defining problems;
- planning and carrying out investigations;
- interpreting, analyzing, and evaluating data;
- constructing and critiquing conclusions and explanations;
- developing and using models; and

- obtaining, evaluating, and communicating information.

"Understand" refers to the application of scientific knowledge including the ability to:

- apply understanding of key science concepts and the nature of science;
- apply information 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;
- think critically, problem-solve, and make decisions;
- make connections with Crosscutting Concepts to allow for deeper understanding. The Crosscutting Concepts are cause and effect; energy and matter; patterns; scale, proportion, and quantity; stability and change; structure and function; and systems and system models. These concepts provide a context through which the standards can be unified throughout the year.

Therefore, the use of "investigate and understand" allows each content standard to become the basis for a broad range of teaching objectives, which school divisions will develop and refine to meet the intent of the 2025 Expanded High School Science *Standards of Learning*

K-12 Safety

Safe learning environments are critical when implementing the 2025 Expanded High School 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 the 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 before their use in an instructional activity. Such information is referenced through Safety Data Sheets (SDS), which conform to the requirements of the Globally Harmonized System of Classification and Labeling of Chemicals (GHS). The identified precautions involving the use of goggles, gloves, aprons, and fume hoods must be followed as prescribed.

The following sources offer further guidance on science safety:

- public health departments' and school divisions' protocols and chemical hygiene plans.
- Occupational Safety and Health Administration;
- International Science and Engineering Fair rules;

- Virginia Department of Education (VDOE) Science Safety Handbook on the VDOE Science Instruction webpage; and
- American Chemical Society (ACS) resources: Safety in the Elementary Science Classroom, Chemical Safety for Teachers and their Supervisors, and Guidelines for Chemical Laboratory Safety on the ACS webpage.

The 2025 Expanded High School Science *Standards of Learning* are informed by the NRC Framework for K-12 Science Education (https://nap.nationalacademies.org/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts) and the Next Generation Science Standards (https://www.nextgenscience.org/).

2025 Environmental Science

Environmental Science examines the mutual relationships between organisms and their environment. Students learn about photosynthesis, recycling and regeneration, ecosystems, population and growth studies, pollution, and conservation of natural resources as they study the relationships among plants, animals, and humans. Instruction should provide opportunities for field experiences and investigations of local ecological systems. The scientific and engineering practices are used as students examine scientific explanations, conduct experiments, analyze and communicate information, gather and use information in scientific literature, and use their science knowledge to solve problems.

ENV.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
   - ask questions that arise from careful observation of phenomena and/or organisms, from examining models and theories, and/or to seek additional information
   - determine which questions can be investigated within the scope of the school laboratory or field
   - make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated
   - generate hypotheses based on research and scientific principles
   - define design problems that involve the development of a process or system with multiple components and criteria

b) planning and carrying out investigations
   - plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate
   - plan and conduct investigations or test design solutions in a safe and ethical manner including considerations of environmental, social, and personal effects
   - select and use appropriate tools and technology to collect and record data
   - determine appropriate sample size and techniques

c) interpreting, analyzing, and evaluating data
   - construct and interpret data tables showing independent and dependent variables, repeated trials, and means
   - construct, analyze, and interpret graphical displays of data and consider limitations of data analysis
   - use data to build and revise models, to support an explanation for phenomena, or test a solution to problems
   - apply mathematical concepts and processes
   - analyze data using tools, technologies, and/or models to make valid and reliable scientific claims or determine an optimal design solution

d) constructing and critiquing conclusions and explanations

- construct and revise explanations based on valid and reliable evidence obtained from a variety of sources including models, theories, simulations, peer review, and students' own investigations
- make quantitative and/or qualitative claims based on data
- apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and design solutions
- compare and evaluate competing arguments or design solutions in light of currently accepted explanations and new scientific evidence
- make and support a claim using empirical evidence and scientific reasoning
- evaluate a claim by applying scientific reasoning, theory, and/or models to link evidence to assess the extent to which the reasoning and data support the explanation or conclusion.
- differentiate among a scientific hypothesis, theory, and law

e) developing and using models
- evaluate the merits and limitations of models
- develop, revise, and/or use models based on evidence to illustrate or predict relationships, to support explanations, predict phenomena, analyze systems, and/or solve problems

f) obtaining, evaluating, and communicating information
- compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem
- gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and credibility of each source
- communicate scientific and/or technical information about phenomena and/or a design process in multiple formats

ENV.2 The student will investigate and understand that matter and energy move within and among Earth's systems.

Demonstration of the essential knowledge and practices includes:

a) Make, support, and evaluate a claim about how Earth is a system composed of interacting components.
b) Explain the importance of the properties and characteristics of water in supporting life processes and Earth systems.
c) Develop and use a model to explain how biogeochemical processes support life and demonstrate the conservation of matter and energy.
d) Develop and use a model of Earth's energy budget to predict how fluctuations and changes in the budget might affect Earth's ability to sustain life.

ENV.3 The student will investigate and understand that processes and systems lead to changes on Earth's surface.

Demonstration of the essential knowledge and practices includes:

a) Plan and conduct an investigation on the effect of processes on Earth's surface.

b) Develop and use a model to explain how processes of the rock cycle change Earth's surface.
c) Make, support, and evaluate a claim about how natural processes and human activities have changed Earth's surface.

ENV.4 The student will investigate and understand that ecosystems are in a state of dynamic equilibrium that is affected by complex biotic and abiotic interactions.
Demonstration of the essential knowledge and practices includes:
a) Compare biotic and abiotic factors in terrestrial and aquatic ecosystems.
b) Describe the ecological role that an organism plays in supporting the overall sustainability of the ecosystem.
c) Make, support, and evaluate a claim about the ecological roles of different categories of species in maintaining or disrupting ecosystem equilibrium.
d) Predict the effect caused by the introduction of an invasive species on the equilibrium of an ecosystem.
a) Develop and use models to predict the effects of energy and matter transfer in ecosystems.
b) Make, support, and evaluate a claim about how energy and matter is conserved in ecosystems.
e) Make, support, and evaluate a claim about how environmental pressures may lead to shifts in ecosystem equilibrium.
f) Explain how ecosystems change over time through succession and how this affects ecosystem dynamics.
c) Predict the effect of natural processes and human activities on Virginia's biodiversity and ecosystem equilibrium.

ENV.5 The student will investigate and understand that changes in population affect biodiversity and ecosystem success.
Demonstration of the essential knowledge and practices includes:
a) Analyze and interpret population growth curves to identify changes in population size.
b) Make, support, and evaluate a claim about the relationship among limiting factors, population size, and carrying capacity.
c) Make, support, and evaluate a claim about the importance of genetic variation on the biodiversity of an ecosystem.
d) Develop and use a model to explain how species diversity is affected by environmental pressures.
e) Explain how human population growth changed over time as a result of various factors and predict the effect of continued growth on the environment.

ENV.6 The student will investigate and understand that Earth's resources are finite and should be conserved.
Demonstration of the essential knowledge and practices includes:
a) Make, support, and evaluate a claim about how sustainable and unsustainable natural resources affect organisms.

b) Compare geologic and chemical processes that are responsible for filtering, cycling, and storing Earth's freshwater resources.
c) Debate advantages and disadvantages of a sustainable practice in a community, in a home, and as an individual.
d) Make, support, and evaluate a claim about how human activities affect Earth's resources.
e) Compare environmental effects related to the various energy sources in Virginia.

ENV.7 The student will investigate and understand that pollutants have physical, chemical, and biological consequences at the local, regional, and global level.

Demonstration of the essential knowledge and practices includes:

a) Use data to identify a land, water, or atmospheric pollutant in the local community and determine possible sources and effects on the environment.
b) Debate advantages and disadvantages of solutions to safely reduce, eliminate, or remediate a land, water, or atmospheric pollutant.
c) Compare the benefits and limitations of remediation methods used with land, water, and atmospheric pollutants.
d) Research a clean-up plan for a designated Environmental Protection Agency Superfund site.

ENV.8 The student will investigate and understand that natural events and human activities affect global climate change.

Demonstration of the essential knowledge and practices includes:

a) Make, support, and evaluate a claim about how human activities affect global climate change.
b) Compare the effects of natural events and human activities on global climate change.
c) Develop and use a model to explain how changes in global temperature affect a specific ecosystem.
d) Make, support, and evaluate a claim about how climate change affects Virginia communities.
e) Research ways to mitigate greenhouse gas emissions and propose solutions to reduce emissions in the school, home, and community.

ENV.9 The student will investigate and understand that individual and collective actions influence environmental sustainability and policy at local, national, and global levels.

Demonstration of the essential knowledge and practices includes:

a) Make, support, and evaluate a claim about how consumer, corporation, and government choices can affect the environment.
b) Compare the priorities of multiple stakeholders involved in an environmental issue that affects global and/or local ecosystem health.
c) Debate advantages and disadvantages of possible solutions to an environmental problem.
d) Research solutions that reduce effects of human activities on natural systems and propose solutions for school, home, and community to reduce these effects.
e) Explain the roles individuals and communities as well as local, national, and global policies play in mitigating the negative effects of human activities on the climate.

2025 Biology II: Advanced Survey of Biology Topics

Usually taken after a comprehensive initial study of biology, Biology II: Advanced Survey of Biology Topics is a survey of biological systems in more detail. Students study cell organization, function, and reproduction, energy transformation, human anatomy and physiology, and the evolution and adaptation of organisms. The scientific and engineering practices are used as students examine scientific explanations, conduct experiments, analyze and communicate information, gather and use information in scientific literature, and use their science knowledge to solve problems.

BIOII.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
   - ask questions that arise from careful observation of phenomena and/or organisms, from examining models and theories, and/or to seek additional information
   - determine which questions can be investigated within the scope of the school laboratory or field
   - make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated
   - generate hypotheses based on research and scientific principles

b) planning and carrying out investigations
   - plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate
   - plan and conduct investigations in a safe and ethical manner including considerations of environmental, social, and personal effects
   - determine appropriate sample size and techniques
   - select and use appropriate tools and technology to collect and record data

c) interpreting, analyzing, and evaluating data
   - construct and interpret data tables showing independent and dependent variables, repeated trials, and means
   - construct, analyze, and interpret graphical displays of data and consider limitations of data analysis
   - use data to build and revise models or to support an explanation for phenomena
   - apply mathematical concepts and processes
   - analyze data using tools, technologies, and/or models to make valid and reliable scientific claims

d) constructing and critiquing conclusions and explanations

- construct and revise explanations based on valid and reliable evidence obtained from a variety of sources including models, theories, simulations, peer review, and students' own investigations
- make quantitative and/or qualitative claims based on data
- apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena
- compare and evaluate competing arguments in light of currently accepted explanations and new scientific evidence
- make and support a claim using empirical evidence and scientific reasoning
- evaluate a claim by applying scientific reasoning, theory, and/or models to link evidence to assess the extent to which the reasoning and data support the explanation or conclusion

e) developing and using models
- evaluate the merits and limitations of models
- develop, revise, and/or use models based on evidence to illustrate or predict relationships, to support explanations, predict phenomena, analyze systems, and/or solve problems
- apply mathematical and statistical concepts and processes in building and revising models, and supporting explanations of phenomena

f) obtaining, evaluating, and communicating information
- compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem
- gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and credibility of each source
- communicate scientific and/or technical information about phenomena in multiple formats

BIOII.2 The student will investigate and understand that cell processes support survival and serve as a foundation for more complex systems in multicellular organisms. *Demonstration of the essential knowledge and practices includes:*

a) Explain how cell structures and organelles interact as a system to maintain homeostasis in the cell and the organism.
b) Develop and use a model to explain how the cell membrane allows for selective permeability and maintains the internal environment of the cell.
c) Make, support, and evaluate a claim about how a cell's form fits its function within a multicellular organism.
d) Develop and use models to explain the different processes of asexual reproduction (budding, vegetative propagation, binary fission, fragmentation, and sporogenesis).
e) Describe how cell communication and cell specialization support cellular processes (regulation of cell growth, cell division, and cell energetics).

f) Plan and conduct an investigation to determine the relationship between feedback mechanisms and homeostasis.

BIOII.3 The student will investigate and understand that the highly complex organization of living systems requires energy transformations and the exchange of matter.
Demonstration of the essential knowledge and practices includes:
a) Compare energy changes associated with anabolic and catabolic metabolic pathways.
b) Develop and use a model to explain the two stages of photosynthesis and describe their interdependence.
c) Make, support, and evaluate a claim about the importance of photosynthesis and respiration in the cycling of matter and transfer of energy within living systems.
d) Plan and conduct an investigation to compare factors that affect enzyme activity and explain how these factors influence energy and matter in living systems.
e) Predict how disruption in enzyme activity will affect energy and matter in living systems.

BIOII.4 The student will investigate and understand that the transfer of heritable information leads to the continuity of life.
Demonstration of the essential knowledge and practices includes:
a) Develop and use a model to explain how processes during sexual reproduction (crossing over, independent assortment, and random gamete combinations) increase genetic diversity.
b) Make, support, and evaluate a claim about the effect of mutations in DNA (frameshift, insertion, deletion, and substitution) or nondisjunction on diversity.
c) Make, support, and evaluate a claim about the type of intra-allelic gene interactions (dominance, incomplete dominance, codominance, and multiple alleles) in a given scenario.
d) Compare gene linkage and sex-linked inheritance with intra-allelic interactions.
e) Predict genotypes and phenotypes from genetic crosses of dihybrid and sex-linked traits in simple organisms.
f) Develop and use a model to explain patterns of polygenic inheritance.

BIOII.5 The student will investigate and understand that evolutionary mechanisms affect the genetic makeup of populations over time.
Demonstration of the essential knowledge and practices includes:
a) Make, support, and evaluate a claim about the effect of selective pressures on species evolution.
b) Explain the effect of changing environmental conditions on the allele frequencies in a population.
c) Develop and use a model to explain how evolutionary factors (gene flow, genetic drift, mutation, non-random mating, and natural selection) change allele frequencies over time.
d) Develop and use a model to explain the effects of inbreeding and genetic drift in small, isolated populations.
e) Make, support, and evaluate a claim about how speciation occurs.

f) Make, support, and evaluate a claim about how evolution happens at the population level.

BIOII.6 The student will investigate and understand that ecosystems are dynamic systems in which energy transfers and matter flows through interactions among living organisms and their environment.

Demonstration of the essential knowledge and practices includes:

a) Explain how the laws of thermodynamics govern energy transfers through ecosystems.
b) Make, support, and evaluate a claim about how energy transfer influences productivity and ecological efficiency across trophic levels.
c) Develop and use a model to explain the cycling of matter in ecosystems through biogeochemical processes (carbon, nitrogen, water, and phosphorus).
d) Analyze the biotic and abiotic factors in an ecosystem and determine how these factors affect patterns of species distribution and population size.
e) Make, support, and evaluate a claim about how species interactions influence ecosystem structure.
f) Make, support, and evaluate a claim about how biodiversity and ecosystem resilience are influenced by natural and human-induced disturbances.

The following standard provides an opportunity for divisions, teachers, and students to explore advanced topics in biology based on student interest, community and workforce needs, and as an opportunity for career exploration. Due to the open nature of this standard, local divisions are to determine the content and rigor expectations for students. Instruction should align with the rigorous expectations of a second-level course and demonstrate an appropriate vertical progression from the expectations in Biology.

BIOII.7 The student will investigate and understand concepts from different fields in biology. Topics may include but are not limited to:

a) Biochemistry.
b) Comparative anatomy.
c) Human health.
d) Genetics and synthetic biology.

2025 Biology II: Anatomy and Physiology

Usually taken after a comprehensive initial study of biology, Biology II: Anatomy and Physiology presents the human body and biological systems in more detail. In order to understand the structure and function of the human body, students study cells and tissues, explore functional systems (skeletal, muscular, cardiovascular, respiratory, digestive, integumentary, nervous, endocrine, immune, excretory, lymphatic, reproductive), and how systems interact to support life processes and maintain homeostasis. The scientific and engineering practices are used as students examine scientific explanations, conduct experiments, analyze and communicate information, gather and use information in scientific literature, and use their science knowledge to solve problems.

AP.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
   - ask questions that arise from careful observation of phenomena and/or organisms, from examining models and theories, and/or to seek additional information
   - determine which questions can be investigated within the scope of the school laboratory or field
   - make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated
   - generate hypotheses based on research and scientific principles

b) planning and carrying out investigations
   - plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate
   - plan and conduct investigations in a safe and ethical manner including considerations of environmental, social, and personal effects
   - determine appropriate sample size and techniques
   - select and use appropriate tools and technology to collect and record data

c) interpreting, analyzing, and evaluating data
   - construct and interpret data tables showing independent and dependent variables, repeated trials, and means
   - construct, analyze, and interpret graphical displays of data and consider limitations of data analysis
   - use data to build and revise models, to support an explanation for phenomena, or test a solution to problems
   - apply mathematical concepts and processes
   - analyze data using tools, technologies, and/or models to make valid and reliable scientific claims

d) constructing and critiquing conclusions and explanations

- construct and revise explanations based on valid and reliable evidence obtained from a variety of sources including models, theories, simulations, peer review, and students' own investigations
- make quantitative and/or qualitative claims based on data
- apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena
- compare and evaluate competing arguments in light of currently accepted explanations and new scientific evidence
- make and support a claim using empirical evidence and scientific reasoning
- evaluate a claim by applying scientific reasoning, theory, and/or models to link evidence to assess the extent to which the reasoning and data support the explanation or conclusion

e) developing and using models
- evaluate the merits and limitations of models
- develop, revise, and/or use models based on evidence to illustrate or predict relationships, to support explanations, predict phenomena, analyze systems, and/or solve problems
- apply mathematical and statistical concepts and processes in building and revising models, and supporting explanations of phenomena

f) obtaining, evaluating, and communicating information
- compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem
- gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and credibility of each source
- communicate scientific and/or technical information about phenomena in multiple formats

AP.2 The student will investigate and understand that body systems work together to maintain homeostasis. Systems studied should include the nervous, endocrine, cardiovascular, respiratory, excretory, and integumentary systems.

Demonstration of the essential knowledge and practices includes:

a) Develop and use models to explain how feedback mechanisms maintain homeostasis.
b) Plann and conduct investigations related to feedback mechanisms and homeostasis.
c) Develop and use models to explain how various body systems help maintain homeostasis.
d) Make, support, and evaluate a claim about how the structure and function of various body systems help maintain homeostasis.
e) Explain a disorder, disease, injury, lifestyle, or a component of aging that affects homeostasis.

AP.3 The student will investigate and understand that body systems work together to enable movement and provide structural support. Systems studied should include the skeletal, nervous, and muscular systems.

Demonstration of the essential knowledge and practices includes:

a) Identify the major components of the skeletal, nervous, and muscular systems.
b) Develop and use models to illustrate the structure and function of body systems in movement and support.
c) Make, support, and evaluate a claim about how the structure of cells and tissues in body systems affect movement and support.
d) Make, support, and evaluate a claim about how movement and support require body systems to work independently and together.
e) Plan and conduct investigations related to movement and support in body systems.
f) Explain a disorder, disease, injury, lifestyle, or a component of aging that affects movement and support.

AP.4 The student will investigate and understand that body systems work together to enable the transport and exchange of substances throughout the body, with the environment, or between tissues. Systems studied should include the cardiovascular, respiratory, lymphatic, digestive, and excretory systems.

Demonstration of the essential knowledge and practices includes:

a) Identify the major components of the cardiovascular, respiratory, lymphatic, digestive, and excretory systems.
b) Develop and use models to illustrate how the structure and function of body systems support transport and exchange.
c) Make, support, and evaluate a claim about how the structure of cells and tissues in body systems affect transport and exchange.
d) Make, support, and evaluate a claim about how transport and exchange require body systems to work independently and together.
e) Plan and conduct investigations related to transport and exchange in body systems.
f) Explain a disorder, disease, injury, lifestyle, or a component of aging that affects transport and exchange.

AP.5 The student will investigate and understand that body systems work together to regulate functions and communicate by receiving, processing, and responding to internal and external stimuli. Systems studied should include the nervous and endocrine systems.

Demonstration of the essential knowledge and practices includes:

a) Identify the major components of the nervous and endocrine systems related to regulation and communication.
b) Develop and use models to illustrate how the structure and function of body systems support regulation and communication.
c) Make, support, and evaluate a claim about how the structure of cells and tissues in body systems affect regulation and communication.
d) Make, support, and evaluate a claim about how regulation and communication require body systems to work independently and together.

e) Plan and conduct investigations related to regulation and communication in body systems.
f) Explain a disorder, disease, injury, lifestyle, or a component of aging that affects regulation and communication.

AP.6 The student will investigate and understand that body systems work together to provide protection and defense from physical damage, pathogens, and other threats. Systems studied should include the integumentary, skeletal, lymphatic, and immune systems.
Demonstration of the essential knowledge and practices includes:
a) Identify the major components of the integumentary, skeletal, lymphatic, and immune systems related to protection and defense.
b) Develop and use models to illustrate how the structure and function of body systems support protection and defense.
c) Make, support, and evaluate a claim about how the structure of cells and tissues in body systems affect protection and defense.
d) Make, support, and evaluate a claim about how protection and defense require body systems to work independently and together.
e) Make, support, and evaluate a claim about the use and/or misuse of therapies in treating or preventing infections.
f) Explain a disorder, disease, injury, lifestyle, or a component of aging that affects the body's ability to protect and defend itself.

AP.7 The student will investigate and understand how body systems work together to support energy production and metabolism by obtaining, transforming, and utilizing resources. Systems studied should include the digestive, respiratory, cardiovascular, and endocrine systems.
Demonstration of the essential knowledge and practices includes:
a) Identify the major components of the digestive, respiratory, cardiovascular, and endocrine systems related to energy and metabolism.
b) Develop and use models to illustrate how the structure and function of body systems support energy and metabolism.
c) Make, support, and evaluate a claim about how the structure of cells and tissues in body systems affect energy and metabolism.
d) Make, support, and evaluate a claim about how energy and metabolism require body systems to work independently and together.
e) Make, support, and evaluate a claim about the importance of nutrition on human health.
f) Plan and conduct investigations related to energy and metabolism in body systems.
g) Explain a disorder, disease, injury, lifestyle, or a component of aging that affects energy and metabolism.

AP.8 The student will investigate and understand that body systems work together to create and develop new life. Systems studied should include the reproductive and endocrine systems.
Demonstration of the essential knowledge and practices includes:

a) Identify the major components of the reproductive and endocrine systems related to reproduction and development.
b) Develop and use models to illustrate how the structure and function of body systems support reproduction and development.
c) Make, support, and evaluate a claim about how the structure of cells and tissues in body systems affect reproduction and development.
d) Make, support, and evaluate a claim about how reproduction and development require body systems to work independently and together.
e) Explain a disorder, disease, injury, lifestyle, or a component of aging that affects reproduction and development.

2025 Biology II: Ecology

Usually taken after a comprehensive initial study of biology and Earth science, Biology II: Ecology is designed to provide students with a more intensive look at ecological concepts. Students study how adaptive processes affect life on Earth, Earth's biosphere, biodiversity, population dynamics, communities and factors that affect ecological stability. Instruction should provide opportunities for field experiences and investigations of local ecological systems. The scientific and engineering practices are used as students examine scientific explanations, conduct experiments, analyze and communicate information, gather and use information in scientific literature, and use their science knowledge to solve problems.

EC.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
- ask questions that arise from careful observation of phenomena and/or organisms or from examining models and theories, or unexpected results, and/or to seek additional information
- determine which questions can be investigated within the scope of the school laboratory or field
- make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated
- generate hypotheses based on research and scientific principles

b) planning and carrying out investigations
- plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate
- plan and conduct investigations in a safe and ethical manner including considerations of environmental, social, and personal effects
- determine appropriate sample size and techniques
- select and use appropriate tools and technology to collect and record data

c) interpreting, analyzing, and evaluating data
- construct and interpret data tables showing independent and dependent variables, repeated trials, and means
- construct, analyze, and interpret graphical displays of data and consider limitations of data analysis
- use data to build and revise models, to support an explanation for phenomena, or test a solution to problems
- apply mathematical concepts and processes
- analyze data using tools, technologies, and/or models to make valid and reliable scientific claims

d) constructing and critiquing conclusions and explanations

- construct and revise explanations based on valid and reliable evidence obtained from a variety of sources including models, theories, simulations, peer review, and students' own investigations
- make quantitative and/or qualitative claims based on data
- apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena
- compare and evaluate competing arguments in light of currently accepted explanations and new scientific evidence
- make and support a claim using empirical evidence and scientific reasoning
- evaluate a claim by applying scientific reasoning, theory, and/or models to link evidence to assess the extent to which the reasoning and data support the explanation or conclusion

e) developing and using models
- evaluate the merits and limitations of models
- develop, revise, and/or use models based on evidence to illustrate or predict relationships, to support explanations, predict phenomena, analyze systems, and/or solve problems
- apply mathematical and statistical concepts and processes in building and revising models, and supporting explanations of phenomena

f) obtaining, evaluating, and communicating information
- compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem
- gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and credibility of each source
- communicate scientific and/or technical information about phenomena in multiple formats

EC.2 The student will investigate and understand that biotic and abiotic factors affect the distribution of species and the diversity of life on Earth.

Demonstration of the essential knowledge and practices includes:

a) Compare the biotic and abiotic characteristics of Earth's principal terrestrial and aquatic biomes.
b) Make, support, and evaluate a claim about how characteristics of biomes affect biodiversity.
c) Plan and conduct a biosurvey to assess the health and condition of a circumscribed natural area.
d) Research a natural or anthropogenic threat, the issues that are causing the threat, and describe potential remediation strategies.
e) Make, support, and evaluate a claim about how the level of biodiversity influences ecosystem resilience and sustainability.
f) Research ways legislation and/or global agreements provide biodiversity protections.
g) Compare benefits and limitations of methods used to increase resilience and sustainability in a local ecosystem.

EC.3 The student will investigate and understand that energy is transferred through ecosystems.

Demonstration of the essential knowledge and practices includes:

a) Explain how the laws of thermodynamics govern energy transfers through ecosystems.
b) Explain how changes in ecosystem factors affect energy transfer and ecological efficiency in a local ecosystem.
c) Make, support, and evaluate a claim about how strategies organisms use to acquire energy lead to biodiversity within ecosystems.
d) Make, support, and evaluate a claim about how nutrient cycling by decomposers affects energy transfer in ecosystems.

EC.4 The student will investigate and understand that matter flows through ecosystems.

Demonstration of the essential knowledge and practices includes:

a) Develop and use a model to explain the cycling of matter in ecosystems through biogeochemical cycles (carbon, nitrogen, water, and phosphorus).
b) Develop and use a model to explain how the movement of one nutrient affects an ecosystem.
c) Analyze and interpret data to predict how changes in the availability of resources will affect species' success in ecosystems.
d) Make, support, and evaluate a claim about how a disruption in a biogeochemical cycle affects an ecosystem.
e) Make, support, and evaluate a claim about how changes in resource availability affect the biodiversity of an ecosystem.

EC.5 The student will investigate and understand that growth within populations is influenced by biotic and abiotic factors.

Demonstration of the essential knowledge and practices includes:

a) Explain how population growth and resource availability affect population dispersion.
b) Analyze data to determine the relationship between population density and resource availability.
c) Analyze data (age structure, r/K strategy, and survivorship curves) to evaluate the viability of a population.
d) Analyze a local ecosystem and categorize limiting factors
e) Analyze population growth curves to determine growth trends, identify limiting factors, and make predictions about future population behavior.

EC.6 The student will investigate and understand that driving forces of ecological relationships support biodiversity.

Demonstration of the essential knowledge and practices includes:

a) Make, support, and evaluate a claim about how natural selection leads to adaptations in species and increases ecosystem biodiversity.
b) Describe the behavioral and physiological adaptations that plants and animals have developed to allow them to survive in diverse ecosystems.

c) Make, support, and evaluate a claim about the roles of adaptive and non-adaptive forces in speciation and biodiversity.
d) Research a real-world example of an organism's adaptation to an evolving environment.
e) Make, support, and evaluate a claim about how species interactions and adaptations are a response to selective pressures.
f) Research real-world structural and behavioral adaptations used by predators and prey for survival.
g) Make, support, and evaluate a claim about how ecological niches and resource partitioning affect interactions within communities.
h) Explain the role predation plays in population size within an ecosystem and differentiate forms of predation.

EC.7 The student will investigate and understand that natural and anthropogenic events affect ecosystems.

Demonstration of the essential knowledge and practices includes:

a) Make, support, and evaluate a claim about the ecological evolution of an ecosystem that is currently experiencing disruption.
b) Develop and use a model to explain ecological succession for a local ecosystem and predict the effect of natural and anthropogenic events on natural succession processes.
c) Make, support, and evaluate a claim about the effect of an invasive species on the stability of a local ecosystem.
d) Make, support, and evaluate a claim about how natural and anthropogenic events affect ecosystem resilience.

2025 Biology II: Genetics

Usually taken after a comprehensive initial study of biology, Biology II: Genetics provides students with an understanding of general concepts concerning genes, heredity, and variation of organisms. Students study chromosomes, the structure of DNA and RNA molecules, and dominant and recessive inheritance. The scientific and engineering practices are used as students examine scientific explanations, conduct experiments, analyze and communicate information, gather and use information in scientific literature, and use their science knowledge to solve problems.

GEN.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
   - ask questions that arise from careful observation of phenomena and/or organisms, from examining models and theories, and/or to seek additional information
   - determine which questions can be investigated within the scope of the school laboratory or field
   - make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated
   - generate hypotheses based on research and scientific principles

b) planning and carrying out investigations
   - plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate
   - plan and conduct investigations in a safe and ethical manner including considerations of environmental, social, and personal effects
   - determine appropriate sample size and techniques
   - select and use appropriate tools and technology to collect and record data

c) interpreting, analyzing, and evaluating data
   - construct and interpret data tables showing independent and dependent variables, repeated trials, and means
   - construct, analyze, and interpret graphical displays of data and consider limitations of data analysis
   - use data to build and revise models, to support an explanation for phenomena, or test a solution to problems
   - apply mathematical concepts and processes, including statistics and probability
   - analyze data using tools, technologies, and/or models to make valid and reliable scientific claims

d) constructing and critiquing conclusions and explanations
   - construct and revise explanations based on valid and reliable evidence obtained from a variety of sources including models, theories, simulations, peer review, and students' own investigations
   - make quantitative and/or qualitative claims based on data

   - apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena
   - compare and evaluate competing arguments in light of currently accepted explanations and new scientific evidence
   - make and support a claim using empirical evidence and scientific reasoning
   - evaluate a claim by applying scientific reasoning, theory, and/or models to link evidence to assess the extent to which the reasoning and data support the explanation or conclusion

e) developing and using models
   - evaluate the merits and limitations of models
   - develop, revise, and/or use models based on evidence to illustrate or predict relationships, to support explanations, predict phenomena, analyze systems, and/or solve problems
   - apply mathematical and statistical concepts and processes in building and revising models, and supporting explanations of phenomena

f) obtaining, evaluating, and communicating information
   - compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem
   - gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and credibility of each source
   - communicate scientific and/or technical information about phenomena in multiple formats

GEN.2 The student will investigate and understand that an organism's genome encodes instructions for the synthesis of proteins.

Demonstration of the essential knowledge and practices includes:

a) Make, support, and evaluate a claim about how DNA allows for the preservation of the genome while still allowing evolution to occur.
b) Develop and use a model to explain how transcription and translation convert a DNA sequence into a polypeptide chain.
c) Develop and use a model to predict the effect of a mutation in DNA.
d) Develop and use a model to explain how amino acid interactions give rise to the three-dimensional shape and function of a protein.
e) Make, support, and evaluate a claim about how the universal genetic code is the result of common ancestry.

GEN.3 The student will investigate and understand that gene expression is regulated in organisms.

a) Demonstration of the essential knowledge and practices includes:
b) Describe the mechanisms for regulation of gene expression in prokaryotes and eukaryotes at the transcription and translation levels.
c) Make, support, and evaluate a claim about the role of introns and exons in gene expression.

d) Explain the effect of different environmental conditions on phenotypic expression resulting from the same genotype.
e) Make, support, and evaluate a claim about the benefits of exercise, diet, and other lifestyle factors or family history on epigenetic gene expression.

GEN.4 The student will investigate and understand that the transmission of heritable information allows for genetic diversity.
Demonstration of the essential knowledge and practices includes:
a) Develop and use a model to explain how processes during sexual reproduction (crossing over, independent assortment, and random gamete combinations) increase genetic diversity.
b) Use models to identify abnormalities in chromosome number and/or structure and hypothesize what meiotic events would result in those changes.
c) Develop and use a model to explain how nondisjunction can affect chromosome number in gametes.
d) Compare sources of diversity in prokaryotes and eukaryotes.
e) Make, support, and evaluate a claim about causes of inheritable genetic variations, including genetic disorders.

GEN.5 The student will investigate and understand that the inheritance of traits is more complex than described through Mendelian genetics.
Demonstration of the essential knowledge and practices includes:
a) Apply rules of probability and statistics to determine if the actual results of a genetic cross fit the predicted results.
b) Develop and use a model to explain Mendelian and non-Mendelian patterns of inheritance, gene linkage, and chromosome mapping (polygenic inheritance, incomplete dominance, sex-linked inheritance, and codominance).
c) Make, support, and evaluate a claim about the importance of mitochondrial DNA.

GEN.6 The student will investigate and understand that the genetic makeup of a population can change.
Demonstration of the essential knowledge and practices includes:
a) Make, support, and evaluate a claim about the effect of evolutionary factors that lead to genetic variation within and among populations.
b) Predict genotypes in a population from observed phenotypes using the Hardy-Weinberg principle.
c) Make, support, and evaluate a claim about why Hardy-Weinberg equilibrium rarely occurs.
d) Make, support, and evaluate a claim about how the genetic composition of populations is the result of natural processes.
e) Make, support, and evaluate a claim about how genetic makeup can be used to classify organisms.

GEN.7 The student will investigate and understand that principles of genetics and genetic engineering have practical applications.

Demonstration of the essential knowledge and practices includes:

a) Research how genetics and genetic engineering are being used in different fields.
b) Make, support, and evaluate a claim about how genetic engineering could be used to address a medical, health, agricultural, or environmental issue.
c) Evaluate information from the popular media about genetic engineering for accuracy, credibility, and bias and compare it with current scientific literature.

2025 Chemistry II: Advanced Survey of Chemistry Topics

Usually taken after a comprehensive initial study of chemistry, Chemistry II: Advanced Survey of Chemistry Topics, is an advanced study of matter and energy. Students study atomic structure, intermolecular forces, reactions, kinetics, and equilibrium. The scientific and engineering practices are used as students examine scientific explanations, conduct experiments, analyze and communicate information, gather and use information in scientific literature, and use their science knowledge to solve problems.

CHII.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
    - ask questions that arise from careful observation of phenomena, examination of a model or theory, unexpected results, and/or to seek additional information
    - determine which questions can be investigated within the scope of the school laboratory or field
    - make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated
    - generate hypotheses based on research and scientific principles

b) planning and carrying out investigations
    - plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate
    - plan and conduct investigations in a safe and ethical manner including considerations of environmental, social, and personal effects
    - determine appropriate sample size and techniques
    - select and use appropriate tools and technology to collect and record data

c) interpreting, analyzing, and evaluating data
    - construct and interpret data tables showing independent and dependent variables, repeated trials, and means
    - construct, analyze, and interpret graphical displays of data and consider limitations of data analysis
    - use data to build and revise models, to support an explanation for phenomena, or test a solution to problems
    - solve problems using mathematical manipulations including the International System of Units (SI), scientific notation, derived units, significant digits, and dimensional analysis
    - analyze data using tools, technologies, and/or models to make valid and reliable scientific claims
    - consider limitations of data analysis including instrument limitations, sampling selection, and measurement error when analyzing and interpreting data
    - differentiate between accuracy and precision of measurements

d) constructing and critiquing conclusions and explanations

- construct and revise explanations based on valid and reliable evidence obtained from a variety of sources including models, theories, simulations, peer review, and students' own investigations
- make quantitative and/or qualitative claims based on data
- apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena
- compare and evaluate competing arguments in light of currently accepted explanations and new scientific evidence
- make and support a claim using empirical evidence and scientific reasoning
- evaluate a claim by applying scientific reasoning, theory, and/or models to link evidence to assess the extent to which the reasoning and data support the explanation or conclusion

e) developing and using models
- evaluate the merits and limitations of models
- develop, revise, and/or use models based on evidence to illustrate or predict relationships, to support explanations, predict phenomena, analyze systems, and/or solve problems
- use models and simulations to visualize and explain the movement of particles, to represent chemical reactions, to formulate mathematical equations, and to interpret data sets
- apply mathematical and statistical concepts and processes in building and revising models, and supporting explanations of phenomena
- derive mathematical models (equations) from experimental data

f) obtaining, evaluating, and communicating information
- compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem
- gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and credibility of each source
- communicate scientific and/or technical information about phenomena in multiple formats

CHII.2 The student will investigate and understand that atoms can be identified by their electron distribution and energy.

Demonstration of the essential knowledge and practices includes:

a) Describe how the quantum mechanical model illustrates our current understanding of the atom.
b) Develop and use a model to explain electron distribution.
c) Develop and use a model to explain the emission and absorption spectra of atoms.
d) Make, support, and evaluate a claim about how spectra can be used to identify elements.

CHII.3 The student will investigate and understand that the electron arrangement in atoms and ions contributes to the type of bonding, structure, and the properties of materials.

Demonstration of the essential knowledge and practices includes:

a) Predict the type of bonding that occurs between elements.
b) Make, support, and evaluate a claim about how Coulomb's law explains the arrangement of the ions in an ionic substance.
c) Develop and use models of molecules (Lewis diagrams, valence shell electron pair repulsion (VSEPR) model, hybrid orbitals) to predict molecular geometry including expanded octets.
d) Plan and conduct an investigation to identify an unknown substance using properties.
e) Make, support, and evaluate a claim about how metallic bonding explains the properties of metallic substances.
f) Make, support, and evaluate a claim about how the atomic and molecular structure of materials determines their function and properties.

CHII.4 The student will investigate and understand that forces of attraction among particles contribute to properties of substances.

Demonstration of the essential knowledge and practices includes:

a) Develop and use a model to explain the strength(s) and type(s) of intermolecular forces (IMF) in substances.
b) Plan and conduct an investigation related to IMF.
c) Make, support, and evaluate a claim about the strength(s) and type(s) of IMF present in substances.
d) Develop and use a model to explain the motion of particles in different phases of matter.
e) Plan and conduct an investigation related to deviations from the ideal gas law.
f) Make, support, and evaluate a claim about deviations from the ideal gas law.
g) Make, support, and evaluate a claim about how IMF affects solubility and separation of mixtures.

CHII.5 The student will investigate and understand that chemical reactions are predictable and quantifiable.

Demonstration of the essential knowledge and practices includes:

a) Develop and use a model to explain changes in matter using balanced equations (chemical, ionic, and net ionic).
b) Make, support, and evaluate a claim about the classification of reactions as oxidation-reduction (redox) or non-redox reactions.
c) Predict the products of chemical reactions.
d) Plan and conduct investigations related to chemical reactions).
e) Perform stoichiometric calculations to determine the amounts of reactants and products.

CHII.6 The student will investigate and understand that rates of a chemical reaction can be observed, measured, and predicted.

Demonstration of the essential knowledge and practices includes:

a) Plan and conduct investigations to determine how factors affect the rate of a chemical reaction.
b) Make, support, and evaluate a claim about why a chemical reaction may or may not occur.
c) Evaluate experimental data to determine the rate and rate law expression for a reaction.
d) Make, support, and evaluate a claim about why a given reaction mechanism is consistent with experimental evidence for a specific reaction.

CHII.7 The student will investigate and understand that many chemical reactions are reversible.

Demonstration of the essential knowledge and practices includes:

a) Determine the equilibrium position based on the equilibrium constant.
b) Calculate equilibrium constant values for equilibrium reactions.
c) Plan and conduct investigations related to equilibrium reactions.
d) Make, support, and evaluate a claim about how changing conditions affect equilibrium reactions.
e) Research how industry uses equilibrium reactions.

The following standard provides an opportunity for divisions, teachers, and students to explore advanced topics in chemistry based on student interest, community and workforce needs, and as an opportunity for career exploration. Due to the open nature of this standard, local divisions are to determine the content and rigor expectations for students. Instruction should align with the rigorous expectations of a second-level course and demonstrate an appropriate vertical progression from the expectations in Chemistry.

CHII.8 The student will investigate and understand concepts from different fields in chemistry.

Topics may include but are not limited to:

a) Thermochemistry.
b) Organic Chemistry.
c) Electrochemistry.
d) Biochemistry.
e) Nuclear Chemistry.

2025 Earth Science II: Advanced Survey of Earth Science Topics

Usually taken after a comprehensive initial study of Earth science, Earth Science II: Advanced Survey of Earth Science Topics, is an advanced study of concepts in Earth science. Students study Earth from a local and global perspective as they learn about time zones, latitude and longitude, atmosphere, weather, climate, matter, and energy transfer. The scientific and engineering practices are used as students examine scientific explanations, conduct experiments, analyze and communicate information, gather and use information in scientific literature, and use their science knowledge to solve problems.

ESII.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
   - ask questions that arise from careful observation of phenomena, examination of a model or theory, or unexpected results, and/or to seek additional information
   - determine which questions can be investigated within the scope of the school laboratory or field
   - make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated
   - generate hypotheses based on research and scientific principles

b) planning and carrying out investigations
   - select and use appropriate tools and technology, including cartographic tools, Geographic Information Systems (GIS), and instruments to collect and record data

c) interpreting, analyzing, and evaluating data
   - construct and interpret data tables showing independent and dependent variables, repeated trials, and means
   - construct, analyze, and interpret graphical displays of data and consider limitations of data analysis
   - use data to build and revise models, to support an explanation for phenomena, or test a solution to problems
   - apply mathematical concepts and processes
   - analyze data using tools, technologies, and/or models to make valid and reliable scientific claims
   - construct and/or interpret map scales, satellite imagery, diagrams, classification charts, graphs, tables, models, geologic cross-sections, and topographic profiles
   - read and interpret topographic and basic geologic maps and globes using a variety of geospatial coordinate systems

d) constructing and critiquing conclusions and explanations

- construct and revise explanations based on valid and reliable evidence obtained from a variety of sources including models, theories, simulations, peer review, and students' own investigations
- make quantitative and/or qualitative claims based on data
- apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena
- compare and evaluate competing arguments in light of currently accepted explanations and new scientific evidence
- make and support a claim using empirical evidence and scientific reasoning
- evaluate a claim by applying scientific reasoning, theory, and/or models to link evidence to assess the extent to which the reasoning and data support the explanation or conclusion

e) developing and using models
   - evaluate the merits and limitations of models
   - develop, revise, and/or use models based on evidence to illustrate or predict relationships, to support explanations, predict phenomena, analyze systems, and/or solve problems
   - construct and/or interpret map scales, satellite imagery, diagrams, classification charts, graphs, tables, models, geologic cross-sections, and topographic profiles
   - read and interpret sun path diagrams, day/night world maps, and other models scientists use to communicate information
   - apply mathematical and statistical concepts and processes in building and revising models, and supporting explanations of phenomena

f) obtaining, evaluating, and communicating information
   - compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem
   - gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and credibility of each source
   - communicate scientific and/or technical information about phenomena in multiple formats

ESII.2 The student will investigate and understand that geospatial analytics is used to simplify complex situations and guide scientific decision-making.

Demonstration of the essential knowledge and practices includes:

a) Interpret maps in terms of decimal degrees and sexagesimal degrees.
b) Explain factors (geographical, political, and practical) that affect the construction of time zones.
c) Make, support, and evaluate a claim about the merits and limitations of longitude and latitude compared to horizontal and vertical datums for an intended purpose.
d) Compare map projections when determining the appropriate map for a specific need.
e) Determine the different map attributes (scale, elevation interval, and land attributes) needed for a specific purpose of the map.
f) Compare different satellite imagery) for an intended purpose.

g) Develop a map based on direct observation and/or technology that supports an explanation, predicts phenomena, analyzes a system, and/or solves a problem.
h) Explain how Global Positioning System satellites are used to calculate positions on the surface of Earth.

ESII.3 The student will investigate and understand that Earth's internal and surface processes produce changes in continental and ocean-floor features.
Demonstration of the essential knowledge and practices includes:
a) Develop and use a model to explain the relationships between plate boundaries and predict phenomena.
b) Develop and use a model to explain plate motion.
c) Make, support, and evaluate claims about the cycling of matter, ages of rocks, distribution of rocks and minerals, and the formation of continental and oceanic features.
d) Explain changes in Earth's surface features by analyzing seismic data (frequency of events, location, depth, magnitude, and stress).
e) Explain the relationship between magma composition and resulting internal and surface features.

ESII.4 The student will investigate and understand that major geological and biological events are recorded in rocks and fossils.
Demonstration of the essential knowledge and practices includes:
a) Make, support, and evaluate a claim about the age of Earth.
b) Make, support, and evaluate a claim about the use of different radioactive isotopes for absolute dating of rock and/or fossils for a location.
c) Analyze the major geologic and biological events in Earth's history in terms of the scale, proportion, and quantity and determine the significance.
d) Make, support, and evaluate a claim about the coevolution of Earth's systems (hydrosphere, lithosphere, atmosphere, and biosphere).
e) Explain the geological events of a region based on correlating rock strata with and without fossils from different locations within a region.
f) Make, support, and evaluate a claim using a variety of sources (rocks, fossil records, and geologic maps) about how changes to climate and ecosystems in Earth's history affected life.
g) Develop and use a timeline to interpret the geologic history of Virginia based on evidence.

ESII.5 The student will investigate and understand that energy transfer into and out of Earth's systems is affected by the dynamics of the sun-Earth system and human activities.
Demonstration of the essential knowledge and practices includes:
a) Develop and use a model to explain how Earth's rotation and revolution around the sun and solar incidence affect atmospheric and biological systems (seasonal changes, length of day, and circadian rhythm).
b) Explain global climate trends over geologic time using Milankovitch cycles and evaluate how current climate change differs in cause, rate, and scale from these natural cycles.

c) Make, support, and evaluate a claim about how solar flares and coronal mass ejections affect technology.
d) Make, support, and evaluate a claim about the effect of sunspot cycles on global average temperatures and compare their effect to how human activities are changing Earth's climate.

ESII.6 The student will investigate and understand that the hydrosphere plays a crucial role in shaping Earth's environment and in supporting life.

Demonstration of the essential knowledge and practices includes:

a) Develop and use a model to explain the processes of the hydrologic cycle and predict the effect of the processes on landscape and life.
b) Explain how the availability and quality of water affect ecosystem dynamics.
c) Explain how salinity and temperature affect oceanic ecosystems (coastal, deep water, estuarine, equatorial, and polar).
d) Develop and use a model to explain major surface oceanic currents and their characteristics (temperature, origin, and direction of motion).
e) Make, support, and evaluate a claim about how major surface currents affect local climates.
f) Develop and use a model to predict the results of interactions among geomorphic characteristics, geological characteristics, and the water budget of the region.
g) Research organizations that are working to solve problems related to freshwater availability and quality.
h) Propose a solution or design a device that addresses a problem of freshwater availability and quality.
i) Make, support, and evaluate a claim about how climate change and human activities affect the hydrosphere.

ESII.7 The student will investigate and understand that the atmosphere is a complex, dynamic system that drives climate, weather, and air quality patterns.

Demonstration of the essential knowledge and practices includes:

a) Make, support, and evaluate a claim about how atmospheric changes affect multiple Earth systems.
b) Propose a solution or design a device that addresses a problem involving air quality.
c) Predict weather conditions by analyzing prevailing wind patterns and air mass interactions.
d) Evaluate the merits and limitations of models to explain relationships and predict local weather.
e) Predict potential changes in the future climate by analyzing long-term climate data.
f) Make, support, and evaluate a claim about how natural atmospheric events and human activities affect global climate.
g) Predict how atmospheric conditions due to climate change affect a specific ecosystem.

The following standard provides an opportunity for divisions, teachers, and students to explore advanced topics in Earth science based on student interest, community and workforce needs, and as an opportunity for career exploration. Due to the open nature of this standard, local divisions are to determine the content and rigor expectations for students. Instruction should align with the rigorous expectations of a second-level course and demonstrate an appropriate vertical progression from the expectations in Earth Science.

ESII.8 The student will explore technological advancements and innovative research in Earth Science. Topics may include but are not limited to:

a) Gravity Recovery and Climate Experiment-Follow-On (GRACE-FO).
b) Global Positioning Systems and Global Information Systems.
c) Geospatial Imaging.
d) Geostationary Operational Environmental Satellites.
e) Geophysical imaging of Earth's deep and shallow interior.
f) Macro and micro mineral analytical techniques.
g) Stable isotope geochemistry.

2025 Earth Science II: Astronomy

Usually taken after a comprehensive initial study of Earth science, Earth Science II: Astronomy provides students the opportunity to study the solar system, stars, galaxies, and interstellar bodies. Students study astronomic instruments and explore theories regarding the origin and evolution of the universe, space, and time. The scientific and engineering practices are used as students examine scientific explanations, conduct experiments, analyze and communicate information, gather and use information in scientific literature, and use their science knowledge to solve problems.

AS.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
- ask questions that arise from careful observation of phenomena, examination of a model or theory, or unexpected results, and/or to seek additional information
- determine which questions can be investigated within the scope of the school laboratory or field
- make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated
- generate hypotheses based on research and scientific principles

b) planning and carrying out investigations
- select and use appropriate tools and technology to collect and record data

c) interpreting, analyzing, and evaluating data
- construct and interpret data tables
- construct, analyze, and interpret graphical displays of data and consider limitations of data analysis
- use data to build and revise models, to support an explanation for phenomena, or test a solution to problems
- apply mathematical concepts and processes
- analyze data using tools, technologies, and/or models to make valid and reliable scientific claims

d) constructing and critiquing conclusions and explanations
- construct and revise explanations based on valid and reliable evidence obtained from a variety of sources including models, theories, simulations, peer review, and students’ own investigations
- make quantitative and/or qualitative claims based on data
- apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena
- compare and evaluate competing arguments in light of currently accepted explanations and new scientific evidence
- make and support a claim using empirical evidence and scientific reasoning

    - evaluate a claim by applying scientific reasoning, theory, and/or models to link evidence to assess the extent to which the reasoning and data support the explanation or conclusion
  e) developing and using models
    - evaluate the merits and limitations of models
    - develop, revise, and/or use models based on evidence to illustrate or predict relationships, to support explanations, predict phenomena, analyze systems, and/or solve problems
    - read and interpret star charts, Sun path diagrams, day/night world maps, and other ways astronomers communicate information
    - apply mathematical and statistical concepts and processes in building and revising models, and supporting explanations of phenomena
    - derive mathematical models (equations) from experimental data
  f) obtaining, evaluating, and communicating information
    - compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem
    - gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and credibility of each source
    - communicate scientific and/or technical information about phenomena in multiple formats

AS.2 The student will investigate and understand that human curiosity and ingenuity across cultures and time have shaped our understanding of the universe.
Demonstration of the essential knowledge and practices includes:
a) Compare the astronomical contributions made by ancient cultures.
b) Describe how ancient people determined sizes of Earth, moon and sun and distances between them, and compare these to current values of sizes and distances.
c) Make, support, and evaluate a claim about how the heliocentric model of the solar system is a better predictor of planetary motion than the geocentric model.
d) Explain how advances in astronomical observations and timekeeping led to more accurate measurements of latitude and longitude, improving navigation and global exploration.
e) Explain how Kepler's laws of planetary motion and Newton's law of universal gravitation advanced earlier models of the solar system and allowed for more accurate predictions of orbital motion.
f) Research how technological advances in observational tools contribute to the development of more accurate models of the cosmos and support modern applications such as navigation, communication, and Earth monitoring.

AS.3 The student will investigate and understand that our current knowledge of the evolution and structure of stars, galaxies, and the universe is based upon examining evidence.
Demonstration of the essential knowledge and practices includes:
a) Compare the information gained from different types of telescopes (radio, optical, infrared, ultraviolet, x-ray, gamma ray, neutrino, and space-based).

b) Explain how attributes of the electromagnetic spectrum are used to determine characteristics of astronomical objects.
c) Make, support, and evaluate a claim about how celestial observations resulted in the Nebular Theory of star formation.
d) Explain the relationship between the energy and luminosity of a star by constructing a Hertzsprung-Russell diagram.
e) Develop and use a model to explain the life stages of stars.
f) Explain how nucleosynthesis resulted in the chemical composition of the cosmos.
g) Describe the characteristics of the Milky Way Galaxy, including size, shape, rotation, stellar distribution, and our place within it.
h) Compare the evolution of galaxies based on their shape and content.
i) Compare techniques that are used to determine astronomical distances.
j) Make, support, and evaluate a claim about the characteristics of the universe (formation, age, composition, expansion, and structure).
k) Develop and use a model to explain the relationships among matter, energy, dark matter, and dark energy.

AS.4 The student will investigate and understand that the solar system has structure, has evolved, and can be used as a model for planetary system formation.
Demonstration of the essential knowledge and practices includes:
a) Infer the age, composition, and evolution of the solar system based on the study of asteroids and meteorites.
b) Make, support, and evaluate a claim about Earth's formation and early history.
c) Compare theories on the formation and evolution of planetary systems (solar nebular theory, condensation theory, core accretion theory, and gravitational instability theory).
d) Describe characteristics of major and minor objects in our solar system.
e) Develop and use a model to explain how interactions between layers of the sun affect Earth.
f) Make, support, and evaluate a claim about how studies of the sun can be used as a model to understand characteristics of stars.
g) Compare the strengths and limitations of methods (transit method, radial velocity, gravitational lensing, direct imaging, and astrometry) used to discover exoplanets.

AS.5 The student will investigate and understand that celestial objects in the Solar System move in well understood paths, producing predictable and observable patterns.
Demonstration of the essential knowledge and practices includes:
a) Explain the effects of the relative positions of Earth, moon, and sun.
b) Predict the path of the moon, sun, stars, and constellations as they move across the sky daily and seasonally based on various locations, times, and dates.
c) Compare the strengths and limitations of astronomical coordinate systems (horizontal system, ecliptic system, equatorial system, and galactic coordinate system).
d) Locate and identify celestial objects using coordinate systems.
e) Develop and use a model to explain sidereal, solar, and synodic time and predict the effects on daily changes in the rise time, set time, and transit of stars.
f) Develop and use a model to explain retrograde motion of planets.

2025 Earth Science II: Geology

Usually taken after a comprehensive initial study of Earth science, Earth Science II: Geology provides an in-depth study of the forces that formed and continue to affect Earth's surface. Students study rocks and minerals, earthquakes, volcanoes, and erosion. The scientific and engineering practices are used as students examine scientific explanations, conduct experiments, analyze and communicate information, gather and use information in scientific literature, and use their science knowledge to solve problems.

GEO.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
   - ask questions that arise from careful observation of phenomena, examination of a model or theory, or unexpected results, and/or to seek additional information
   - determine which questions can be investigated within the scope of the school laboratory or field
   - make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated
   - generate hypotheses based on research and scientific principles

b) planning and carrying out investigations
   - plan and conduct observational and experimental investigations
   - plan and conduct investigations in a safe and ethical manner including considerations of environmental, social, and personal effects
   - determine appropriate sample size and techniques
   - select and use appropriate tools and technology including hand specimens, topographic maps and other types of contour maps, geologic maps, surveying compass, image processing, digital electronic tools, and other scientific instruments to collect and record data

c) interpreting, analyzing, and evaluating data
   - construct and interpret data tables showing independent and dependent variables, repeated trials, and means
   - construct, analyze, and interpret graphical displays of data and consider limitations of data analysis
   - use data to build and revise models, to support an explanation for phenomena, or test a solution to problems
   - apply mathematical concepts and processes
   - analyze data using tools, technologies, and/or models to make valid and reliable scientific claims

d) constructing and critiquing conclusions and explanations
   - construct and revise explanations based on valid and reliable evidence obtained from a variety of sources including models, theories, simulations, peer review, and students' own investigations
   - make quantitative and/or qualitative claims based on data

- apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena
- compare and evaluate competing arguments in light of currently accepted explanations and new scientific evidence
- make and support a claim using empirical evidence and scientific reasoning
- evaluate a claim by applying scientific reasoning, theory, and/or models to link evidence to assess the extent to which the reasoning and data support the explanation or conclusion

e) developing and using models
- evaluate the merits and limitations of models
- develop, revise, and/or use models based on evidence to illustrate or predict relationships, to support explanations, predict phenomena, analyze systems, and/or solve problems
- construct and/or interpret map scales, satellite imagery, diagrams, classification charts, graphs, tables, models, geologic cross-sections, and topographic profiles
- read and interpret topographic and basic geologic maps and globes, including location by latitude and longitude
- apply mathematical and statistical concepts and processes in building and revising models, and supporting explanations of phenomena

f) obtaining, evaluating, and communicating information
- compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem
- gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and credibility of each source
- communicate scientific and/or technical information about phenomena in multiple formats

GEO.2 The student will investigate and understand that <u>minerals form in different ways, and that their makeup and structure affect their properties, how they are identified, where they are found, and how they are used everyday life.</u>

Demonstration of the essential knowledge and practices includes:

a) Develop and use a model to explain mineral formation and the resulting characteristics.
b) Explain how the structure of a mineral results in specific mineral properties.
c) Plan and conduct an investigation to determine the physical and chemical characteristics of minerals and explain how these are used in mineral identification.
d) Make, support, and evaluate a claim about the cost and benefits of obtaining, refining, and utilizing mineral resources.
e) Analyze the distribution of mineral resources of Virginia and compare Virginia’s mineral resources to global distribution.
f) Evaluate how the properties of minerals determine their use.

GEO.3 The student will investigate and understand that rocks form and change through Earth processes over time, that they are identified using their properties, and how they are used in everyday life.

Demonstration of the essential knowledge and practices includes:

a) Develop and use a model to explain how rock types can form and transform into other rocks through processes and geologic time.
b) Develop and use models (Bowen Reaction Series, crystal growth, weathering, erosion, and lithification) to explain and predict how surface and internal processes relate to rock formations and their characteristics.
c) Plan and conduct an investigation to determine the physical and chemical characteristics of rocks and explain how these characteristics are used to identify rocks.
d) Make, support, and evaluate a claim about how the properties of rocks determine their use.

GEO.4 The student will investigate and understand that major geological and biological events are evident in rocks and fossils.

Demonstration of the essential knowledge and practices includes:

a) Make, support, and evaluate a claim about the age of Earth.
b) Make, support, and evaluate a claim about which radioactive isotope could be used to date a location.
c) Explain the significance of major geologic and biological events in Earth's history.
d) Make, support, and evaluate a claim about the coevolution of Earth's systems (hydrosphere, lithosphere, atmosphere, and biosphere).
e) Make, support, and evaluate a claim about how changes to ecosystem dynamics may have led to extinction.
f) Infer the geological events of a region based on correlating rock strata with and without fossils from different locations within a region.
g) Make, support, and evaluate a claim about climate changes in Earth's history.
h) Make, support, and evaluate a claim about the geologic history of Virginia and areas around the globe.

GEO.5 The student will investigate and understand that volcanic activity and seismic data provide evidence of Earth's internal structure, ongoing geologic processes, resulting surface features, and inform hazard mitigation efforts.

Demonstration of the essential knowledge and practices includes:

a) Develop and use a model to explain volcanic processes, forces, resulting surface and subsurface features, and predict potential hazards to communities.
b) Explain the relationship among magma composition, volcanic activity, and resulting landforms.
c) Determine the location of earthquake epicenters using seismic data.
d) Infer Earth's internal structures and locate earthquake focus and epicenters using velocities and the travel paths of seismic waves.
e) Develop and use models to explain effects of earthquake intensities and predict potential damage to communities.

f) Debate advantages and disadvantages of solutions to reduce the effects of earthquakes or volcanoes on society.

GEO.6 The student will investigate and understand that the theory of plate tectonics explains the past and current movements of rocks at Earth's surface and provides a framework for understanding the changes in Earth's surface.

Demonstration of the essential knowledge and practices includes:

a) Develop and use a model to explain how internal tectonic forces and processes result in plate movement.
b) Make, support, and evaluate a claim about how plate tectonics explains the age of rocks in different locations.
c) Make, support, and evaluate a claim about how the distribution of rocks and minerals observed in a given location today reflects past tectonic activity.
d) Make, support, and evaluate a claim to explain the location and size of continents and oceans.
e) Develop and use a model to explain tectonic events that created Virginia's physiographic provinces.

GEO.7 The student will investigate and understand that weathering, erosion, and deposition processes shape Earth's surface landforms.

Demonstration of the essential knowledge and practices includes:

a) Develop and use a model to explain how agents of weathering, erosion, and deposition continually shape landforms.
b) Plan and conduct an investigation about how variables influence rates of weathering, erosion, and deposition.
c) Identify a problem and propose a solution related to weathering, erosion, and/or deposition.
d) Make, support, and evaluate a claim about how Virginia's landscape has changed over geologic history as a result of weathering, erosion, and deposition.
e) Make, support, and evaluate a claim about how one change to Earth's surface can create feedback mechanisms that affect other Earth systems.

2025 Earth Science II: Oceanography

Usually taken after a comprehensive initial study of Earth science, Earth Science II: Oceanography provides students the opportunity to study the content, features, and possibilities of Earth's oceans. Students explore marine organisms, conditions, and ecology. The scientific and engineering practices are used as students examine scientific explanations, conduct experiments, analyze and communicate information, gather and use information in scientific literature, and use their science knowledge to solve problems.

OC.1 The student will demonstrate an understanding of scientific and engineering practices by

- a) asking questions and defining problems
    - ask questions that arise from careful observation of phenomena and/or organisms, from examining models and theories, and/or seeking additional information
    - determine which questions can be investigated within the scope of the school laboratory or field
    - make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated
    - generate hypotheses based on research and scientific principles
    - define design problems that involve the development of a process or system with interacting components, criteria, and constraints
- b) planning and carrying out investigations
    - plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate
    - plan and conduct investigations or test design solutions in a safe and ethical manner including considerations of environmental, social, and personal effects
    - determine appropriate sample size and techniques
    - select and use appropriate tools and technology to collect and record data
- c) interpreting, analyzing, and evaluating data
    - construct and interpret data tables showing independent and dependent variables, repeated trials, and means
    - construct, analyze, and interpret graphical displays of data and consider limitations of data analysis
    - use data to build and revise models, to support an explanation for phenomena, or test a solution to problems
    - apply mathematical concepts and processes
    - analyze data using tools, technologies, and/or models to make valid and reliable scientific claims or determine an optimal design solution
    - analyze data to optimize a design
- d) constructing and critiquing conclusions and explanations

- construct and revise explanations based on valid and reliable evidence obtained from a variety of sources including models, theories, simulations, peer review, and students' own investigations
- make quantitative and/or qualitative claims based on data
- apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and design solutions
- compare and evaluate competing arguments or design solutions in light of currently accepted explanations and new scientific evidence
- make and support a claim using empirical evidence and scientific reasoning
- evaluate a claim by applying scientific reasoning, theory, and/or models to link evidence to assess the extent to which the reasoning and data support the explanation or conclusion

e) developing and using models
   - evaluate the merits and limitations of models
   - develop, revise, and/or use models based on evidence to illustrate or predict relationships, to support explanations, predict phenomena, analyze systems, and/or solve problems
   - apply mathematical and statistical concepts and processes in building and revising models, supporting explanations of phenomena, or testing solutions to problems

f) obtaining, evaluating, and communicating information
   - compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem
   - gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and credibility of each source
   - communicate scientific and/or technical information about phenomena and/or a design process in multiple formats

OC.2 The student will investigate and understand that ocean ecosystems support a great diversity of life.

Demonstration of the essential knowledge and practices includes:

a) Explain how biotic and abiotic factors affect biodiversity within marine ecosystems.
b) Make, support, and evaluate a claim about factors that promote and control the locations of primary productivity and its effect on ocean ecosystems.
c) Identify characteristics of major groups (kingdom, phylum, and class) of marine organisms.
d) Make, support, and evaluate a claim about how unique morphological features of marine organisms help them survive and thrive in their respective marine niches.
e) Explain the benefit of daily vertical migration for zooplankton and its effects on ocean ecosystems.
f) Develop and use a model to predict the transfer of energy within ocean ecosystems and predict the effects of natural and anthropogenic events on ecosystem health.

g) Compare the relative roles of chemosynthesis and photosynthesis in biological productivity of ocean ecosystems.
h) Debate advantages and disadvantages of a solution to a natural or anthropogenic threat to a marine organism.

OC.3 The student will investigate and understand that the properties of seawater enable distinct biological and physical characteristics within the ocean and ecosystems.
Demonstration of the essential knowledge and practices includes:
a) Explain how the properties of seawater (pH, dissolved oxygen, turbidity, density, and salinity) affect biodiversity in ocean ecosystems.
b) Plan and conduct an investigation to determine how salinity affects density of water.
c) Make, support, and evaluate a claim about the relationship between the density and depth of seawater.
d) Explain how the relationships among temperature, density, depth, and salinity can be used to predict effects on ocean currents.
e) Explain how the properties of the thermocline, halocline, and pycnocline create distinct ecosystems.
f) Describe the variation of the transmission of light through zones of the ocean and determine biological adaptations that allow organisms to survive within each zone.
g) Analyze data to understand the relationship among dissolved gases, temperature, and pressure with increasing depth and effects on marine life.
h) Develop and use a model to explain thermohaline circulation and the effect on ecosystems.
i) Plan and conduct an investigation that demonstrates the ocean's capacity to serve as a buffer and predict the effects of changing pH levels on marine ecosystems.

OC.4 The student will investigate and understand that there are interactions between the ocean and the atmosphere that influence weather, climate, and ocean systems.
Demonstration of the essential knowledge and practices includes:
a) Explain how water moderates regional climate and local weather conditions.
b) Develop and use a model to explain why the Coriolis Effect occurs and how it influences global wind patterns and oceanic surface currents.
c) Identify major surface currents, their characteristics (temperature, origin, and direction of motion) and explain how they affect local climates.
d) Predict the formation and severity of low-pressure tropical systems over the ocean and describe potential hazards when they reach land.
e) Develop and use a model to explain interrelationships among wind, ocean current, and climate patterns.
f) Explain the atmospheric causes of Ekman transport and its effect on marine and climate systems.
g) Make, support, and evaluate a claim about how climate variability and change influence ocean currents and stratification.
h) Make, support, and evaluate a claim about how atmospheric changes affect ocean systems.

OC.5 The student will investigate and understand that Earth's geologic, atmospheric, and astronomical processes interact with the ocean to shape its physical features, movement, and coastal environments.

Demonstration of the essential knowledge and practices includes:

a) Make, support, and evaluate a claim about the role of plate tectonics in shaping the physical features of the ocean and continents.
b) Explain how dynamic events at plate boundaries (earthquakes, volcanoes, seafloor spreading, and hot spots) influence oceans and continents.
c) Develop and use a model to explain the relative position of the sun, moon, and Earth to predict spring and neap tides.
d) Explain the role of gravitational forces among Earth, moon, and sun and resulting tides.
e) Interpret a tide table to determine tidal range and the type of daily tides (diurnal, semi-diurnal, mixed, and continental interference).
f) Develop and use a model to explain how factors (wind duration, fetch, and wind speed) lead to the formation of ocean waves.
g) Compare different types of waves and how coastal shorelines change the dynamic of the waves.
h) Develop and use a model to explain the formation of barrier islands and how they form a defense against rising sea level and storm waves.
i) Research and describe events of how waves, tides, and/or sea level change affected the physical structure of a local coastline.
j) Compare the advantages and disadvantages of hard and soft stabilization methods on coastline stabilization.
k) Research and describe the origin, composition, particle size, thickness, and distribution of oceanic sediments, including their classification.

OC.6 The student will investigate and understand that historic and on-going oceanic explorations contribute to the understanding of ocean systems.

Demonstration of the essential knowledge and practices includes:

a) Research past and modern explorations to explain how exploration contributes to understanding the ocean.
b) Describe how historical and current tools, mapping technologies (lead-line, echo sounding, multi-beam sonar, seismic profiling, side-scan sonar, and sea surface altimetry), and the contributions of research vessels have expanded human understanding of ocean ecosystems.
c) Research major developments in the understanding of ocean systems and processes.
d) Make, support, and evaluate a claim about the effect of natural and anthropogenic events on ocean ecosystems using modern satellite imagery and data sets.
e) Identify a current global problem and propose a solution based on understanding ocean systems.

OC.7 The student will investigate and understand that the ocean is of important social and economic value globally and in Virginia.

Demonstration of the essential knowledge and practices includes:

a) Make, support, and evaluate a claim about how the extraction of physical and biological resources from the ocean affects marine ecosystems.
b) Compare global consumerism to our national and local trends and explain these effects on Virginia, local coastal, and offshore environments.
c) Make, support, and evaluate a claim about the benefits and drawbacks of various uses of the ocean.
d) Research local and global issues, policies, and laws that promote responsible stewardship of the oceans.
e) Debate advantages and disadvantages of the law of the sea.
f) Design, evaluate, and refine a solution for reducing the effects of a natural event or a human activity on Virginia's ocean systems, shorelines, local communities, and on ecosystem biodiversity.
g) Make, support, and evaluate a claim about how continued coastal population growth in Virginia affects sustainability.

2025 Physics II: Advanced Survey of Physics Topics

Usually taken after a comprehensive initial study of physics, Physics II: Advanced Survey of Physics, is a survey of advanced concepts in physics. Students study laws of conservation, thermodynamics, kinetics, wave and particle phenomena, electromagnetic fields, and fluid dynamics. The scientific and engineering practices are used as students examine scientific explanations, conduct experiments, analyze and communicate information, gather and use information in scientific literature, and use their science knowledge to solve problems.

PHII.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
   - ask questions that arise from careful observation of phenomena, examination of a model or theory, or unexpected results, and/or seek additional information
   - determine which questions can be investigated within the scope of the school laboratory or field
   - make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated
   - generate hypotheses based on research and scientific principles
   - define design problems that involve the development of a process or system with interacting components and criteria and constraints

b) planning and carrying out investigations
   - plan and conduct observational and experimental investigations; identify variables, constants, and controls where appropriate
   - plan and conduct investigations or test design solutions in a safe and ethical manner including considerations of environmental, social, and personal effects
   - determine appropriate sample size and techniques
   - select and use appropriate tools and technology to collect and record data

c) interpreting, analyzing, and evaluating data
   - construct and interpret data tables showing independent and dependent variables, repeated trials, and means
   - construct, analyze, and interpret graphical displays of data, including slope, intercept, and area under the curve, and consider limitations of data analysis
   - use data to build and revise models, to support an explanation for phenomena, or test a solution to problems
   - solve problems using mathematical manipulations including the International System of Units (SI), scientific notation, derived units, significant digits, and dimensional analysis
   - analyze data using tools, technologies, and/or models to make valid and reliable scientific claims or determine an optimal design solution
   - consider limitations of data analysis including instrument limitations, sampling selection, and measurement error when analyzing and interpreting data

- differentiate between accuracy and precision of measurements
- analyze data to optimize a design

d) constructing and critiquing conclusions and explanations
- construct and revise explanations based on valid and reliable evidence obtained from a variety of sources including models, theories, simulations, peer review, and students' own investigations
- make quantitative and/or qualitative claims based on data
- apply scientific ideas, principles, and/or evidence to explain phenomena or design solutions
- compare and evaluate competing arguments or design solutions in light of currently accepted explanations and new scientific evidence
- make and support a claim using empirical evidence and scientific reasoning
- evaluate a claim by applying scientific reasoning, theory, and/or models to link evidence to assess the extent to which the reasoning and data support the explanation or conclusion

e) developing and using models
- evaluate the merits and limitations of models
- develop, revise, and/or use models based on evidence to illustrate or predict relationships, to support explanations, predict phenomena, analyze systems, and/or solve problems
- apply mathematical and statistical concepts and processes in building and revising models, supporting explanations of phenomena, or testing solutions to problems
- derive mathematical models (equations) from experimental data

f) obtaining, evaluating, and communicating information
- compare, integrate, and evaluate sources of information presented in different media or formats to address a scientific question or solve a problem
- gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and credibility of each source
- communicate scientific and/or technical information about phenomena and/or a design process in multiple formats

PHII.2 The student will investigate and understand that fields are generated by mass and charge and that these fields govern the motion of objects and enable interactions at a distance. *Demonstration of the essential knowledge and practices includes:*

a) Compare the motions of charged objects within electric fields to motions of objects within gravitational fields.
b) Plan and conduct an investigation to determine the relationship between force strength, distance, and/or orientation of magnetic materials.
c) Plan and conduct an investigation to determine the relationship between a current carrying wire and the resulting magnetic field.
d) Develop and use models to visualize, explain, and predict interactions involving electromagnetic and gravitational fields.

e) Propose a solution to a problem that can be solved using the knowledge of magnetic induction.
f) Propose a solution to a problem involving an induced current.
g) Explain how the properties of magnets define their application in different systems.

PHII.3 The student will investigate and understand that momentum in a system is governed by conservation laws.

Demonstration of the essential knowledge and practices includes:

a) Explain the relationship between impulse and momentum found in real-world systems.
b) Develop and use models to predict pre-collision and post-collision scenarios of elastic and inelastic collisions.
c) Make, support, and evaluate a claim that linear and angular momentum can be used to analyze revolving objects, whereas angular momentum must be used to describe rotating objects.
d) Solve problems involving the angular momentum of rotating objects found in real-world systems.
e) Plan and conduct an investigation related to conservation of angular momentum.

PHII.4 The student will investigate and understand that energy in a system is governed by conservation laws.

Demonstration of the essential knowledge and practices includes:

a) Analyze a real-world system to determine energy transfers and transformations.
b) Plan and conduct an investigation to determine the relationship between work, power, and efficiency.
c) Design, build, test, and refine an apparatus that maximizes the efficiency of a closed system.
d) Evaluate the efficiency of simple real-world systems and justify improvements to efficiency.
e) Plan and conduct an investigation to confirm that energy is conserved in translational and rotational systems.
f) Develop and use models to visualize, explain, and predict interactions involving angular displacement, angular velocity, angular acceleration, and moment of inertia found in real-world systems.
g) Apply principles of torque to industrial tools and real-world scenarios.

PHII.5 The student will investigate and understand that thermal energy processes affect energy transformations.

Demonstration of the essential knowledge and practices includes:

a) Plan and conduct an investigation to determine relationships among thermal energy, work, and temperature.
b) Develop and use models and mathematical representations to explain the relationships between thermal energy and work.
c) Make predictions of entropy and thermal energy changes in systems and processes when energy is transferred.

d) Create, evaluate, and refine solutions to problems related to thermal conductivity.

PHII.6 The student will investigate and understand that the behavior of fluids is related to the confines of the systems.

Demonstration of the essential knowledge and practices includes:

a) Develop and use models and mathematical representations to describe energy, pressure, temperature, and volume in a variety of real-world systems.
b) Plan and conduct an investigation to predict relationships between fluid pressure, velocity, and elevation.
c) Apply concepts of laminar fluid flow to real-world systems.
d) Develop and use a model to explain how mechanical advantage can be made by confined fluids.
e) Use data and evidence to explain fluid movement through a system by applying principles of conservation laws.
f) Identify a simple problem in a system of fluid flow and justify a solution through the application of Bernoulli's principle.

PHII.7 The student will investigate and understand that electromagnetic radiation behaves both as particles and as waves.

Demonstration of the essential knowledge and practices includes:

a) Explain the relationship among energy, frequency, and wavelength of electromagnetic waves emitted by objects at various temperatures.
b) Plan and conduct investigations to demonstrate the nature of light as both a transverse wave and a particle.
c) Make, support, and evaluate a claim about whether the particle model or wave model is more useful.
d) Explain how technological devices work.

PHII.8 The student will investigate and understand that quantum mechanics, general relativity, and special relativity show that the properties of space and time are not absolute.

Demonstration of the essential knowledge and practices includes:

a) Compare classical and quantum models in explaining the photoelectric effect.
b) Describe the effect of gravitational fields on how light travels.
c) Compare how very large and very small systems are approached in classical physics and modern physics.
d) Research and communicate technological advancements that use the properties of the Doppler Effect, gravitational wave variation, relativity, or quantum mechanics.

The following standard provides an opportunity for divisions, teachers, and students to explore advanced topics in physics based on student interest, community and workforce needs, and as an opportunity for career exploration. Due to the open nature of this standard, local divisions are to determine the content and rigor expectations for students. Instruction should align with the rigorous expectations of a second-level course and demonstrate an appropriate vertical progression from the expectations in Physics.

PHII.9 The student will investigate and understand technological advancements and innovative research in physics fields.

Demonstration of the essential knowledge and practices includes:

a) Develop and use a model to explain how modern electric power systems operate.
b) Explore topics in modern physics including nuclear, solid state, nanotechnology, superconductivity, the standard model, and dark matter, dark energy, and their effects on current technologies.
c) Debate the merits of the pursuit of pure science or applied science.