Ohio's Learning Standards and Model Curriculum

Science

STANDARDS ADOPTED FEBRUARY 2018
MODEL CURRICULUM ADOPTED MAY 2019

Ohio | Department of Education

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Introduction

OVERVIEW

This overview outlines the visions and goals of *Ohio's Learning Standards and Model Curriculum for Science*, provides the guiding principles that framed the development of the materials and contains the definitions used in the document. The *Expectations for Learning* encompasses the *Nature of Science* and the *Cognitive Demands*. This overview introduces the *Nature of Science,* which is the foundation for all aspects of science instruction. It also contains definitions for the *Cognitive Demands*.

VISION

Each Child, Our Future is Ohio's five-year strategic plan to ensure each student enjoys a bright future thanks to an excellent preK-12 education experience. The plan's vision is for each child to be *challenged* to discover and learn, *prepared* to pursue a fulfilling post-high school path and *empowered* to become a resilient, lifelong learner who contributes to society.

The strategic plan details four equal learning domains that contribute to the holistic success of each child. These include foundational knowledge and skills, well-rounded content, leadership and reasoning skills and social-emotional learning. *Ohio's Learning Standards and Model Curriculum for Science* support the four domains.

Ohio's Learning Standards and Model Curriculum for Science serves as a basis for what all students should know and be able to do in order to become scientifically literate citizens, equipped with knowledge and skills for the 21st century workforce and higher education. Ohio educators are provided with the content and expectations for learning at each grade level. From this information, district curriculum can be developed. By the end of high school, students should graduate with sufficient proficiency in science to:

- Know, use and interpret scientific explanations of the natural world;
- Generate and evaluate scientific evidence and explanations, distinguishing science from pseudoscience;
- Understand the nature and development of scientific knowledge;
- Participate productively in scientific practices and discourse.[1]

[1]*Taking Science to School Learning and Teaching Science in Grades K-8.* National Research Council of the National Academies.

> "Knowledge of science can enable us to think critically and frame productive questions. Without scientific knowledge, we are wholly dependent on others as "experts." With scientific knowledge, we are empowered to become participants rather than merely observers. Science, in this sense, is more than a means for getting ahead in the world of work. It is a resource for becoming a critical and engaged citizen in a democracy."
> Michaels, S., Shouse, A.W., & Schweingruber H. A. (2008). *Ready, Set, SCIENCE!* Washington DC: The National Academies Press.

The K-8 and high school sections are designed to provide guidance for educators who have the responsibility to teach science to Ohio students. Each *Content Statement* and *Content Elaboration* presents what students should know about that science. The accompanying *Expectations for Learning* incorporates the *Nature of Science* and the *Cognitive Demands*. The *Visions into Practice* section offers optional examples of tasks that students may perform to learn about the science as well as demonstrate their mastery of grade level materials.

It is the blending of the *Content Statements* and *Content Elaborations* with the *Expectations for Learning* (*Cognitive Demands* and *Nature of Science*) that provides the basis for future assessments.

GOALS

Ohio's student-centered goals (Duschl et. al., 2007; Bell et. al. 2009) for science education include helping students:

1. Experience excitement, interest and motivation to learn about phenomena in the natural and physical world.
2. Come to generate, understand, remember and use concepts, explanations, arguments, models and facts related to science.
3. Manipulate, test, explore, predict, question, observe and make sense of the natural and physical world.
4. Reflect on science as a way of knowing; on processes, concepts and institutions of science; and on their own process of learning about phenomena.
5. Participate in scientific activities and learning practices with others, using scientific language and tools.
6. Think about themselves as science learners and develop an identity as someone who knows about, uses and sometimes contributes to science.

These goals are consistent with the expectations of Ohio law.

GUIDING PRINCIPLES

Ohio's Learning Standards and Model Curriculum for Science has been informed by international and national studies, education stakeholders and academic content experts. The guiding principles include:

- **Definition of Science:** Scientific knowledge is logical, predictive and testable, and expands and advances as new evidence is discovered. Science is a process of continuing investigation, based on observation, scientific hypothesis testing, measurement, experimentation and theory building which leads to explanations of natural phenomena, processes or objects that are open to further testing and revision based on evidence.
- **Scientific and Engineering Practices:**
  1. Asking questions (for science) and defining problems (for engineering)
  2. Developing and using models
  3. Planning and carrying out investigations
  4. Analyzing and interpreting data
  5. Using mathematics and computational thinking
  6. Constructing explanations (for science) and designing solutions (for engineering)
  7. Engaging in argument from evidence
  8. Obtaining, evaluating, and communicating information[3]

[3] National Research Council. 2012. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington, DC: The National Academies Press.

- **21st Century Skills:** 21st century skills are integral to the science standards and curriculum development revision documents. They are an essential part of the model curriculum component through the incorporation and integration of scientific inquiry, science skills and process and technological and engineering design. As enumerated by ORC 3301.079, these skills include: creativity and innovation; critical thinking, problem solving and communication; information, media and technological literacy; personal management, productivity, accountability, leadership and responsibility; and interdisciplinary, project-based, real-world learning opportunities.
- **Technological Design:** Technological design is a problem or project-based way of applying creativity, science, engineering and mathematics to meet a human need or want. Modern science is an integrated endeavor. Technological design integrates learning by using science, technology, engineering and mathematics and fosters 21st Century Skills.
- **Technology and Engineering:** Technology modifies the natural world through innovative processes, systems, structures and devices to extend human abilities. Engineering is design under constraint that develops and applies technology to satisfy human needs and wants. Technology and engineering, coupled with the knowledge and methods derived from science and mathematics, profoundly influence the quality of life.
- **Depth of Content:** It is vital that the *Content Statements* and *Content Elaborations* within this document communicate the most essential concepts and the complexity of the discipline in a manner that is manageable and accessible for teachers. The focus is on what students must know to master the specific grade-level content. The *Expectations for Learning* provides the means by which students can demonstrate this grade-level mastery.
- **Internationally Benchmarked:** *Ohio's Learning Standards and Model Curriculum for Science* incorporates research from investigations of the science standards of:
  - Countries whose students demonstrate high-performance on both the Trends in International Mathematics and Science Studies (TIMSS) and Program in Student Assessment (PISA) tests; and
  - States with students who perform well on the National Assessment of Education Progress (NAEP).17

  As a result, there is a clear focus on rigor, relevance, coherence and organization, with an emphasis on horizontal and vertical articulation of content within and across disciplines.
- **Assessment:** Ohio's assessment system will be informed by and aligned with the *Content Statements*, *Content Elaborations* and *Expectations for Learning.*
- **Standards and Curriculum:** *Ohio's Learning Standards and Model Curriculum* provides a framework from which local curricula can be developed. It is not the curriculum. The curriculum will continue to be a local responsibility.

FORMAT AND DEVELOPMENT OF THE STANDARDS AND MODEL CURRICULUM

Ohio's Learning Standards and Model Curriculum is a web-based resource that identifies the content to be instructed and provides examples for implementation in science classrooms through *Expectations for Learning* and the accompanying *Visions into Practice*. While this document focuses on what is most essential, it does not describe all that teachers can or should teach. Teachers and curriculum developers maintain a great deal of discretion in this area.

Work on revision of the standards and model curriculum took place between November 2016 and December 2018, with input from numerous stakeholders from around the state. Three surveys collected input from the public, and more than 175 individuals contributed to updating this document based on survey comments. Various professional and industrial organizations related to science sent representatives to serve on an advisory group overseeing the standards revision process.

The goal of these changes is to improve science education in grades K-12 by providing clarity, focus and a logical, vertical progression in each discipline. All Ohio students deserve rigorous, scientifically accurate instruction that makes them college or career ready and scientifically literate members of society. These standards and model curriculum serve as a road map for Ohio science teachers to use as they customize instruction to fit the individual needs of their particular students. Additional instructional supports will be made available over time.

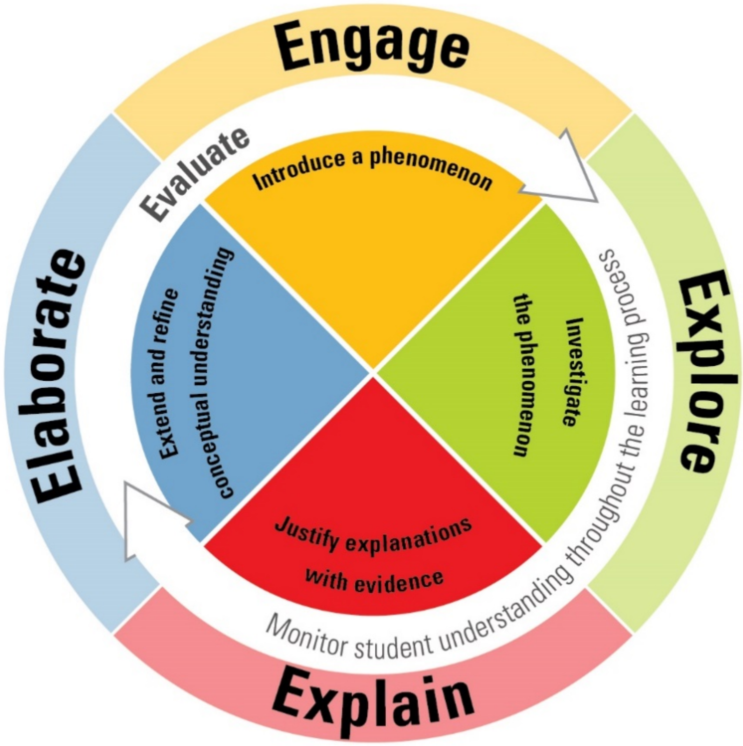
TRANSITION PERIOD

Ohio's Learning Standards for Science will be fully implemented in the 2020-2021 school year to allow educators time to align instruction and resources to the revised standards.

Teachers can begin to transition to the new materials by becoming familiar with the *Nature of Science* and the updated *Visions into Practice,* along with updates to the *Standards* and *Content Elaborations*. The *Nature of Science* distinguishes science as a discipline and describes how scientific knowledge is advanced. This section includes guidelines that contribute to the development of scientific literacy for all students. It is a knowledge of the constructs and values that are intrinsic to science. This material needs to be embedded continuously with all content. *Visions into Practice* provides examples for the *Expectations for Learning* framed by the *Cognitive Demands*. All components of the *Model Curriculum* are compatible with the 5E Learning Cycle (see page 6).

Scientific and engineering practices incorporate universal skills, such as collaboration, critical thinking, problem-solving, communication, research and meta-cognition that are commonly thought of as 21st century process skills. Engaging students in these practices allows them to learn and demonstrate both scientific, technological and engineering design skills that address the goals of career and college readiness.

5E LEARNING CYCLE



By using the 5E Learning Cycles teachers will be able to:

- Provide supports to students as they learn to frame questions, assess and analyze data, and create and critique explanations (including engaging with others in a public forum) – all important components of scientific and engineering practices.
- Select instructional materials that promote the teaching and learning of science by using scientific and engineering practices.
- Assess students' abilities in multiple ways that are compatible with scientific and engineering practices.

Students engaging with grade-appropriate science content through scientific and engineering practices and the 5E Learning Cycle will be better prepared to meet the challenges as they enter higher education or pursue careers.

Model Curriculum Definitions

Strands: Earth and space sciences; physical sciences; and life sciences The Nature of Science is an umbrella over all the content standards and is embedded in each stand.

Grade Band Themes: These are the overarching ideas that connect the strands and topics within the grades. Themes illustrate a progression of increasing complexity from grade to grade that is applicable to all the strands.

Strand Connections: These are the overarching ideas that connect the strands and topics within a grade. Connections help illustrate the integration of the content statements from the different strands.

Topics: These are the main focus for content for each strand at that particular grade level. The topics are the foundation for the specific content statements.

Content Statements: These state the science content to be learned. These are the "what" of science that should be accessible to students at each grade level to prepare them to learn about and use scientific knowledge, principles and processes with increasing complexity in subsequent grades.

Note: *The content statements and associated model curriculum may be taught in any order. The sequence provided here does not represent the Ohio Department of Education-recommended sequence as there is no recommended sequence.*

Model Curriculum: The model curriculum is a web-based resource that incorporates information on "how" the material in the content statement may be taught. It includes content elaborations and learning expectations.

Content Elaboration: This section provides anticipated grade-level depth of content knowledge and examples of science process skills that should be integrated with the content. This section also provides information to help identify what prior knowledge students should have and toward what future knowledge the content will build.

Expectations for Learning: This section includes *Ohio's Cognitive Demands for Science* and the *Nature of Science*. The *Nature of Science* distinguishes science as a discipline and describes how scientific knowledge is advanced. This section includes guidelines that contribute to the development of scientific literacy for all students. It is a knowledge of the constructs and values that are intrinsic to science. This material needs to be embedded continuously within all content. *Ohio's Cognitive Demands for Science* are intrinsically related to current understandings and research about how people learn. They provide a structure for teachers and assessment developers to reflect on plans for teaching science, monitor observable evidence of student learning and develop summative assessment of student learning of science. The cognitive demands include designing technological and engineering solutions using science concepts, demonstrating science knowledge, interpreting and communicating science concepts and recalling accurate science. *Visions into practice* provide examples of how to implement the cognitive demands.

Table 1: Nature of Science

Nature of Science One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.	
Categories	**K-2**
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Apply knowledge of science content to real-world challenges. • Plan and conduct simple scientific investigations using appropriate safety techniques based on explorations, observations and questions. • Employ simple equipment and tools to gather data and extend the senses. • Use data and mathematical thinking to construct reasonable explanations. • Communicate with others about investigations and data.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past, and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	• The world is discovered through exploration. • Exploration leads to observation. Observation leads to questions. • Natural events happen today as they happened in the past. • Events happen in regular patterns and cycles in the natural world.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• Everyone explores the world which generates questions. • The answer is not always as important as the process. • Questions often lead to other questions. • Discoveries are communicated and discussed with others. • People address questions through collaboration with peers and continued exploration. • Everyone can see themselves as scientists.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• It is essential to learn how to identify credible scientific evidence. • Ideas are revised based on new, credible scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Table 1: Nature of Science (continued)

Nature of Science One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.	
Categories	**3-5**
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Observe and ask questions about the world that can be answered through scientific investigations. • Design and conduct scientific investigations using appropriate safety techniques. • Use appropriate mathematics, tools and techniques to gather data and information. • Develop and communicate descriptions, models, explanations and predictions. • Think critically and ask questions about the observations and explanations of others. • Communicate scientific procedures and explanations. • Apply knowledge of science content to real-world challenges.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	• Science is both a body of knowledge and processes to discover new knowledge. • Science is a way of knowing about the world around us based on evidence from experimentation and observations. • Science assumes that objects and events occur in consistent patterns that are understandable through measurement and observation.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• People from many generations and nations contribute to science knowledge. • People of all cultures, genders, and backgrounds can pursue a career in science. • Scientists often work in teams. • Science affects everyday life. • Science requires creativity and imagination.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• Science develops theories based on a body of scientific evidence. • Science explanations can change based on new scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Table 1: Nature of Science (continued)

Nature of Science One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.	
Categories	**6-8**
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Apply knowledge of science content to real-world challenges. • Identify questions that can be answered through scientific investigations. • Design and conduct scientific investigations using appropriate safety techniques. • Use appropriate mathematics, tools and techniques to gather data and information. • Analyze and interpret data. • Develop descriptions, models, explanations and predictions. • Think critically and logically to connect evidence and explanations. • Recognize and analyze alternative explanations and predictions. • Communicate scientific procedures and explanations. • Design technological/engineering solutions.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	• Science is a way of knowing about the world around us based on evidence from experimentation and observations. • Science is a continual process and the body of scientific knowledge continues to grow and change. • Science assumes that objects and events occur in consistent patterns that are understandable through measurement and observation. • Science should carefully consider and evaluate all data including outliers. • Science is based on observable phenomena and empirical evidence. • Science disciplines share common rules for obtaining and evaluating empirical evidence.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• Individuals from different social, cultural, and ethnic backgrounds work as scientists and engineers. • Scientists and engineers are guided by habits of mind, such as intellectual honesty, tolerance of ambiguity, skepticism and openness to ideas. • Scientists and engineers rely on human qualities such as persistence, precision, reasoning, logic, imagination and creativity.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• Science explanations are subject to revision and improvement in light of additional scientific evidence or new understanding of scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Table 1: Nature of Science (continued)

Nature of Science One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.	
Categories	**High School**
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Identify questions and concepts that guide scientific investigations. • Design and conduct scientific investigations using a variety of methods and tools to collect empirical evidence, observing appropriate safety techniques. • Use technology and mathematics to improve investigations and communications. • Formulate and revise explanations and models using logic and scientific evidence (critical thinking). • Recognize and analyze explanations and models. • Communicate and support scientific arguments.

Science is a Way of Knowing
Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.
	• Various science disciplines use diverse methods to obtain evidence and do not always use the same set of procedures to obtain and analyze data (i.e., there is no one scientific method).
	  o Make observations and look for patterns.
	  o Determine relevant independent variables affecting observed patterns.
	  o Manipulate an independent variable to affect a dependent variable.
	  o Conduct an experiment with controlled variables based on a question or hypothesis.
	  o Analyze data graphically and mathematically.
	• Science disciplines share common rules of evidence used to evaluate explanations about natural phenomenon by using empirical standards, logical arguments and peer reviews.
	  o Empirical standards include objectivity, reproducibility, and honest and ethical reporting of findings.
	  o Logical arguments should be evaluated with open-mindedness, objectivity and skepticism.
	• Science arguments are strengthened by multiple lines of evidence supporting a single explanation.
	• The various scientific disciplines have practices, methods, and modes of thinking that are used in the process of developing new science knowledge and critiquing existing knowledge.

Nature of Science One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.	
Categories	**High School**
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• Science depends on curiosity, imagination, creativity and persistence. • Individuals from different social, cultural, and ethnic backgrounds work as scientists and engineers. • Science and engineering are influenced by technological advances and society; technological advances and society are influenced by science and engineering. • Science and technology might raise ethical, social and cultural issues for which science, by itself, does not provide answers and solutions.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• Science can advance through critical thinking about existing evidence. • Science includes the process of comparing patterns of evidence with current theory. • Some science knowledge pertains to probabilities or tendencies. • Science should carefully consider and evaluate anomalies (persistent outliers) in data and evidence. • Improvements in technology allow us to gather new scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Table 2: Ohio's Cognitive Demands for Science

COGNITIVE DEMAND	DESCRIPTION
DESIGNING TECHNOLOGICAL/ENGINEERING SOLUTIONS USING SCIENCE CONCEPTS (T)	Requires student to solve science-based engineering or technological problems through application of scientific inquiry. Within given scientific constraints, propose or critique solutions, analyze and interpret technological and engineering problems, use science principles to anticipate effects of technological or engineering design, find solutions using science and engineering or technology, consider consequences and alternatives, and/or integrate and synthesize scientific information.
DEMONSTRATING SCIENCE KNOWLEDGE (D)	Requires student to use scientific practices and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather and organize data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. (Slightly altered from National Science Education Standards)
INTERPRETING AND COMMUNICATING SCIENCE CONCEPTS (C)	Requires student to use subject-specific conceptual knowledge to interpret and explain events, phenomena, concepts and experiences using grade-appropriate scientific terminology, technological knowledge and mathematical knowledge. Communicate with clarity, focus and organization using rich, investigative scenarios, real-world data and valid scientific information.
RECALLING ACCURATE SCIENCE (R)	Requires student to provide accurate statements about scientifically valid facts, concepts and relationships. Recall only requires students to provide a rote response, declarative knowledge or perform routine mathematical tasks. This cognitive demand refers to students' knowledge of science fact, information, concepts, tools, procedures (being able to describe how) and basic principles.

As with all other frameworks and cognitive demand systems, Ohio's system has overlap between the categories. *Recalling Accurate Science* is a part of the other three cognitive demands included in Ohio's framework, because science knowledge is required for students to demonstrate scientific literacy.

Description of a Scientific Model

A scientific model is a mental construct that represents a large-scale system or process. The model may be abstract, conceptual, mathematical, graphical and/or computer based. Scientific models are valuable for promoting understanding of interactions within and between systems and explaining and predicting observed phenomena as simply as possible. It is important to note that scientific models are incomplete representations of the actual systems and phenomena. They can change over time as new evidence is discovered that cannot be explained using the old model. Since the goal of a model is to promote understanding, simpler, less complete models still can be used when more advanced and complex models do little to contribute to the understanding of the phenomenon considered. For example, the quantum model of the atom would not necessarily be the best model to use to understand the behavior of gases.

TOPICS BY GRADE LEVEL

SCIENCE INQUIRY, PRACTICES AND APPLICATIONS
During the years of **K to grade 4**, all students must develop the ability to: Observe and ask questions about the natural environment; Plan and conduct simple investigations; Employ simple equipment and tools to gather data and extend the senses; Use appropriate mathematics with data to construct reasonable explanations; Communicate about observations, investigations and explanations; and Review and ask questions about the observations and explanations of others.

THEMES	GRADE	THE PHYSICAL SETTING		THE LIVING ENVIRONMENT
		EARTH AND SPACE SCIENCE	**PHYSICAL SCIENCE**	**LIFE SCIENCE**
Observations of the Environment This theme focuses on helping students develop the skills for systematic discovery to understand the science of the natural world around them in greater depth by using scientific inquiry.	**K**	Living and nonliving things have specific physical properties that can be used to sort and classify. The physical properties of air and water are presented as they apply to weather.		
		Daily and Seasonal Changes	**Properties of Everyday Objects and Materials**	**Physical and Behavioral Traits of Living Things**
	1	Energy is observed through movement, heating, cooling and the needs of living organisms.		
		Sun, Energy and Weather	**Motion and Materials**	**Basic Needs of Living Things**
	2	Living and nonliving things may move. A moving object has energy. Air moving is wind and wind can make a windmill turn. Changes in energy and movement can cause change to organisms and the environments in which they live.		
		The Atmosphere	**Changes in Motion**	**Interactions within Habitats**
Interconnections within Systems This theme focuses on helping students explore the components of various systems and then investigate dynamic and sustainable relationships within systems using scientific inquiry.	**3**	Matter is what makes up all living and nonliving substances on Earth. Matter has specific properties and exists in different states. Earth's resources are made of matter. Matter can be used by living things for materials and energy. There are many different forms of energy. Each living component of an ecosystem is composed of matter and uses energy.		
		Earth's Resources	**Matter and Forms of Energy**	**Behavior, Growth and Changes**
	4	Heat and electrical energy are forms of energy that can be transferred from one location to another. Matter has properties that allow the transfer of heat and electrical energy. Heating and cooling affect the weathering of Earth's surface and Earth's past environments. The processes that shape Earth's surface and the fossil evidence found can help decode Earth's history.		
		Earth's Surface	**Electricity, Heat and Matter**	**Earth's Living History**

SCIENCE INQUIRY AND APPLICATIONS
During the years of **grades 5 through 8**, all students must have developed the ability to: Identify questions that can be answered through scientific investigations; Design and conduct a scientific investigation; Use appropriate mathematics, tools and techniques to gather data and information; Analyze and interpret data; Develop descriptions, models, explanations and predictions; Think critically and logically to connect evidence and explanations; Recognize and analyze alternative explanations and predictions; and Communicate scientific procedures and explanations.

<table>
<tr><th rowspan="2">THEMES</th><th rowspan="2">GRADE</th><th colspan="2">THE PHYSICAL SETTING</th><th>THE LIVING ENVIRONMENT</th></tr>
<tr><th>EARTH AND SPACE SCIENCE</th><th>PHYSICAL SCIENCE</th><th>LIFE SCIENCE</th></tr>
<tr><td rowspan="2">Interconnections within Systems
This theme focuses on helping students explore the components of various systems and then investigate dynamic and sustainable relationships within systems using scientific inquiry.</td><td rowspan="2">5</td><td colspan="3">Cycles on Earth, such as those occurring in ecosystems, in the solar system, and in the movement of light and sound result in describable patterns. Speed is a measurement of movement. Change in speed is related to force and mass. The transfer of energy drives changes in systems, including ecosystems and physical systems.</td></tr>
<tr><td>Cycles and Patterns in the Solar System</td><td>Light, Sound and Motion</td><td>Interactions within Ecosystems</td></tr>
<tr><td rowspan="6">Order and Organization
This theme focuses on helping students use scientific inquiry to discover patterns, trends, structures and relationships that may be inferred from simple principles. These principles are related to the properties or interactions within and between systems.</td><td rowspan="2">6</td><td colspan="3">All matter is made of small particles called atoms. The properties of matter are based on the order and organization of atoms and molecules. Cells, minerals, rocks and soil are all examples of matter.</td></tr>
<tr><td>Rocks, Minerals and Soil</td><td>Matter and Motion</td><td>Cellular to Multicellular</td></tr>
<tr><td rowspan="2">7</td><td colspan="3">Systems can exchange energy and/or matter when interactions occur within systems and between systems. Systems cycle matter and energy in observable and predictable patterns.</td></tr>
<tr><td>Cycles and Patterns of Earth and the Moon</td><td>Conservation of Mass and Energy</td><td>Cycles of Matter and Flow of Energy</td></tr>
<tr><td rowspan="2">8</td><td colspan="3">Systems can be described and understood by analysis of the interaction of their components. Energy, forces and motion combine to change the physical features of Earth. The changes of the physical Earth and the species that have lived on Earth are found in the rock record. For species to continue, reproduction must be successful.</td></tr>
<tr><td>Physical Earth</td><td>Forces and Motion</td><td>Species and Reproduction</td></tr>
</table>

Ohio's Learning Standards for Science

Kindergarten

INTRODUCTION TO CONTENT STATEMENTS

GRADE BAND THEME: OBSERVATIONS OF THE ENVIRONMENT

This theme focuses on helping students develop the skills for systematic discovery to understand the science of the natural world around them in greater depth by using scientific inquiry.

STRANDS

Strand Connections: Living and nonliving things have specific physical properties that can be used to sort and classify. The physical properties of air and water are presented as they apply to weather.

EARTH AND SPACE SCIENCE (ESS)	PHYSICAL SCIENCE (PS)	LIFE SCIENCE (LS)
Topic: Daily and Seasonal Changes This topic focuses on observing, exploring, describing and comparing weather changes, patterns in the sky and changing seasons.	**Topic: Properties of Everyday Objects and Materials** This topic focuses on the production of sound and on observing, exploring, describing and comparing the properties of objects and materials with which the student is familiar.	**Topic: Physical and Behavioral Traits of Living Things** This topic focuses on observing, exploring, describing and comparing living things in Ohio.
CONDENSED CONTENT STATEMENTS		
K.ESS.1: Weather changes are long-term and short-term. **K.ESS.2:** The moon, sun and stars can be observed at different times of the day or night.	**K.PS.1:** Objects and materials can be sorted and described by their properties. **K.PS.2:** Some objects and materials can be made to vibrate and produce sound.	**K.LS.1:** Living things have specific characteristics and traits. **K.LS.2:** Living things have physical traits and behaviors, which influence their survival.

NATURE OF SCIENCE GRADES K-2

Nature of Science
One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.

Categories	K-2
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Apply knowledge of science content to real-world challenges. • Plan and conduct simple scientific investigations using appropriate safety techniques based on explorations, observations and questions. • Employ simple equipment and tools to gather data and extend the senses. • Use data and mathematical thinking to construct reasonable explanations. • Communicate with others about investigations and data.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past, and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	• The world is discovered through exploration. • Exploration leads to observation. Observation leads to questions. • Natural events happen today as they happened in the past. • Events happen in regular patterns and cycles in the natural world.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• Everyone explores the world which generates questions. • The answer is not always as important as the process. • Questions often lead to other questions. • Discoveries are communicated and discussed with others. • People address questions through collaboration with peers and continued exploration. • Everyone can see themselves as scientists.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• It is essential to learn how to identify credible scientific evidence. • Ideas are revised based on new, credible scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Complete *Nature of Science* document is found on pages 8-12.

Kindergarten continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Daily and Seasonal Changes
This topic focuses on observing, exploring, describing and comparing weather changes, patterns in the sky and changing seasons.

CONTENT STATEMENT

K.ESS.1: Weather changes are long-term and short-term.

Weather changes occur throughout the day and from day to day.

Air is a nonliving substance that surrounds Earth and wind is air that is moving.

Wind, temperature and precipitation can be used to document short-term weather changes that are observable.

Yearly weather changes (seasons) are observable patterns in the daily weather changes.

Note: *The focus is on observing the weather patterns of seasons. The reason for changing seasons is not appropriate for this grade level; this is found in grade 7.*

CONTENT ELABORATION

Kindergarten Concepts

Wind, temperature and precipitation are components of the weather that can be observed and measured for kindergarten. The measurements collected and tools used can be nonstandard and must be age appropriate. For example, the temperature may be above or below a given point (warmer or colder) or the amount of snow may be marked on a dowel rod to check the depth.

Weather measurements should be collected on a regular basis throughout the school year and then compared, explained and discussed each week and each month. At the end of the school year, a comparison can be made and seasons can be identified by the patterns that were measured throughout the year. Consistent review and questioning to deepen understanding are essential.

Use technology to study weather events, record classroom data, compare classroom data to local data, communicate and share data with other classrooms.

Future Application of Concepts
Grades 1-2: The properties of water and air are explored as they relate to the weather observations and measurement from kindergarten.

Grades 3-5: Different states of water are defined in Physical Sciences. Wind and water are recognized as agents that can change the surface of Earth through weathering and erosion. The observed seasons from kindergarten are related to the sun and the tilt and orbit of Earth in grade 7.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Weather station			
As a class, make a portable weather station that can measure wind, temperature and precipitation amounts. Test and select the best location for the weather station (so that accurate readings can be collected). Design and build a device to measure rainfall amounts. This can be done individually or as a class.	Test different methods or tools to collect precipitation amounts (rain, snow or ice), and measure the speed (faster or slower) and direction of wind (which way the wind is blowing). Ask questions about what happens next, such as: When the wind increases, what happens to the temperature? **Note:** *Nonstandard measurements can be used to meet this objective (e.g., using a dowel to measure the depth of snow).*	Graph weather measurements over time and discuss any patterns that emerge. Graphs can be saved to compare the weather trends of each season. Create an in-class weather station data display center as a place to document the daily weather.	Recognize that temperature, wind and precipitation are aspects of weather that can be measured. Identify the four seasons and the temperature and precipitation measurements that characterize each season. Dress a character appropriately for the day's weather.
Bubbles in the wind			
	Compare the speed (fast, slow) and direction of the wind in different outside areas. Create an investigation, using bubbles to discover there is wind energy, even though you cannot normally see it.	Create a poster or other graphic demonstrating which way the bubbles were blowing. Compare and discuss what was happening.	Explain the connection between wind energy and bubble movement (i.e., the wind determines the direction and speed the bubbles move).

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Weather walks Take weather walks during or after different weather events.			
	Create an investigation highlighting different weather events (e.g., sun casting shadows, wind socks to measure wind, puddles of water after a rain)	Keep a journal of observations on the walks. Draw pictures of the weather observations. Discuss and compare different walks (seasonal).	Describe different types of weather (seasonal characteristics).

Kindergarten continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Daily and Seasonal Changes
This topic focuses on observing, exploring, describing and comparing weather changes, patterns in the sky and changing seasons.

CONTENT STATEMENT	CONTENT ELABORATION
K.ESS.2: The moon, sun and stars can be observed at different times of the day or night. The moon, sun and stars appear in different positions at different times of the day or night. Sometimes the moon is visible during the night, sometimes the moon is visible during the day and at other times the moon is not visible at all. The observable shape of the moon changes in size very slowly throughout the month. The sun is visible only during the day. The sun's position in the sky appears to change in a single day and from season to season. Stars are visible at night, some are visible in the evening or morning and some are brighter than others.	**Kindergarten Concepts** Changes in the position of the sun in the sky can be measured and recorded at different times during the school day. Observations can also be made virtually. This data can be compared from month to month to monitor changes. Stars, groups of stars and different phases of the moon can be observed through books or virtually and documented throughout the month. The names of the stars, constellations or moon phases are not appropriate for kindergarten; only the changes in appearances that can be observed are included. At times, the moon can be observed in the daylight. Drawings, photographs or other graphics can be used to document student observations. Demonstrating (either 3-D or virtual) and testing/experimenting (through kits or models) can be used to explain the changing positions (in the sky) of the sun, stars and moon. Review, question and discuss the demonstrations and observations to deepen understanding. **Future Application of Concepts** **Grades 1-2:** The sun is introduced as a primary source of energy that relates to long- and short-term weather changes. **Grades 3-5:** The sun is the only star in the solar system and celestial bodies orbit the sun. **Grades 6-8:** The tilt and orbit of Earth and position of the sun are related to the seasons.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	Sun and shadows		
As a class, design and make a sun garden. The garden may contain rocks or other objects that reflect or react to sunlight, such as sundials, solar-powered lights or chimes that require sunlight for movement. Place the garden based on sun-shadow data (see demonstrating science knowledge). The design should be drawn on a map and discussed by the class.	Experiment with shadows from the sun. Questions to explore include: What happens to a shadow throughout the day? Can the length of a shadow be measured? How does the shape of the shadow change? Can shadows be made inside? Use light bulbs, overhead projectors, virtual investigations or combinations of the above to explore inside shadows.	Collect and record sun-shadow data on a regular basis throughout the school day and school year. Interpret the changes (length, position) in the shadows. Discuss the changes that are observed, the relationship between the changes in the shadows and the positions of the sun throughout day and in the different seasons. Present findings orally and/or graphically.	Recognize that the sun changes position in the sky during the day.
	Sundial clock		
Design and create a sundial to place outside.	Using a sundial clock, create an experiment or activity to discover and interpret changes in the shadow.	Create a table or chart (e.g., sundial plot, shadow plot) to document changes in shadows throughout the day. Discuss the reasons for the changes.	
	Day and night		
	Create an investigation to discover why the sun is only visible in the day (e.g., globe and flashlight).	Observe the sky during the day and night and record what is observed. Compare and discuss similarities and differences of the daytime sky and nighttime sky. Make drawings of the sky at different times during the day and year. Monthly, discuss changes and compare charts from fall, winter, spring and summer. Make a table or chart to document the changes in the observable (lit) part of the moon throughout a month. Compare the differences throughout the month and then determine if the same pattern exists the next month.	Identify the season with the most and least amount of daylight hours. Discuss how and why the daytime and nighttime skies are different.

Kindergarten continued

PHYSICAL SCIENCE (PS)

Topic: Properties of Everyday Objects and Materials
This topic focuses on the production of sound and on observing, exploring, describing and comparing the properties of objects and materials with which the student is familiar.

CONTENT STATEMENT	CONTENT ELABORATION
K.PS.1: Objects and materials can be sorted and described by their properties. Objects can be sorted and described by the properties of the materials from which they are made. Some of the properties can include color, size and texture.	**Kindergarten Concepts** In kindergarten, the concept that objects are made of specific materials (e.g., clay, cloth, paper, metal, glass) is reinforced. Objects have certain properties (e.g., color, shape, size, temperature, odor, texture, flexibility) that can be described, compared and sorted. Students should not use the sense of taste as a way of observing an unknown substance. Observations are limited to descriptors such as hot, warm, cold, heavy and light. Comparisons of objects are a precursor to measurement. Comparisons are used to sort and describe objects (e.g., is the wooden block heavier or lighter than the plastic block?). Standard and nonstandard measuring tools can give additional information about the environment and can be used to make comparisons of objects and events. Magnifiers can be used to see detail that cannot be seen with the unaided eye. Familiar objects from home, the classroom or the natural environment can be explored and investigated. **Future Application of Concepts** **Grades 1-2:** Changes in objects are investigated, including temperature changes, solid-liquid phase changes and possible changes in amount of liquid water in open and/or closed containers. **Grades 3-5:** Matter is defined. Measurements of weight and liquid volume are made. The mass and kind of material remains the same when an object is reshaped or broken into pieces. The properties of solids, liquids and gases (air) and phase changes are explored. Differentiating between mass and weight is not necessary at this grade level.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	**Demonstrating science knowledge**	**Interpreting and communicating science concepts**	**Recalling accurate science**
Properties of materials			
Design and create a house that can survive strong winds (e.g., the big bad wolf). Provide building materials (e.g., tape, different sized craft sticks, cardboard, pipe cleaners, cereal boxes, feathers, straws). Compare classroom designs and determine which design feature can withstand the strongest winds (fan speed).	Use standard or nonstandard measurements to compare and order objects (e.g., heavier, longer).	Use observable (touch, sight, hearing, smell) information to categorize items by creating a system of organization using one or more physical properties such as size, shape, color, texture, smell and weight. Create a visual representation, using pictures and/or words to explain the sort.	Describe different properties of objects.

Kindergarten continued

PHYSICAL SCIENCE (PS)

Topic: Properties of Everyday Objects and Materials
This topic focuses on the production of sound and on observing, exploring, describing and comparing the properties of objects and materials with which the student is familiar.

CONTENT STATEMENT

K.PS.2: Some objects and materials can be made to vibrate to produce sound.

Sound is produced by touching, blowing or tapping objects. The sounds that are produced vary depending on the properties of objects. Sound is produced when objects vibrate.

CONTENT ELABORATION

Kindergarten Concepts
Sound can be made in many ways. Objects like cymbals, the tabletop or drums can be tapped to produce sound. Objects like a rubber band or a guitar string can be plucked to produce sound. Objects like a bottle or a trumpet can be blown into to produce sound. A wide variety of sounds can be made with the same object (e.g., a plastic bottle could be tapped or blown into). The connection between sound energy and the vibration of an object must be made. Vibrations can be made visible as water splashes when a cymbal or triangle is placed in water or when rice vibrates on the top of a banging drum. The concepts of pitch (low vs. high notes) and volume (loudness) are introduced. Sound needs to be experienced, investigated and explored through observations and experimentation. Standard, virtual and student-constructed instruments can be used to explore sound. Wave descriptions of sound and the propagation of sound energy are not appropriate at this grade level.

Future Application of Concepts
Grades 1-2: Exploring sound provides an experiential basis for the concepts of motion and energy. A variety of motions is explored. Forces are needed to change the motion of objects.

Grades 3-5: Energy is introduced as something that can make things move or cause change. The concept of a medium for sound is introduced and disturbances in liquid and solid media are observed.

Grades 6-8: The wave nature of sound is introduced.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Sound			
Design and make an instrument that can produce different sounds by tapping, plucking or blowing. Evaluate the set of instruments created and make suggestions on how the instruments may make different types of sounds. Design and create a sound garden (e.g., wind chime) using a variety of materials such as plastic, wood and metal.	Explore different ways sounds can be made from an object (e.g., horn, cymbals, rubber band, guitar, plastic bottle). Investigate different amounts of water in cups of the same size and shape to illustrate different sounds. Investigate how the amount of stretch of plucked rubber bands affects the sound. Investigate how different materials or combinations of materials make different sounds.	Compare different ways to make loud and soft sounds by tapping, blowing or plucking objects. Compare different sounds and describe how the tones are different. Observe and listen to a sound garden on a rainy day, windy day and sunny day. Discuss any differences.	Identify three ways to make sounds from objects. Explain that vibrating materials make sounds. Describe ways to change the loudness of a sound (e.g., blow more air through a whistle, bang harder on a drum).

Kindergarten continued

LIFE SCIENCE (LS)

Topic: Physical and Behavioral Traits of Living Things
This topic focuses on observing, exploring, describing and comparing living things in Ohio.

CONTENT STATEMENT	CONTENT ELABORATION
K.LS.1: Living things have specific characteristics and traits. Living things grow and reproduce. Living things are found worldwide.	**Kindergarten Concepts** The emphasis of this content statement is to build a grade-appropriate understanding of what it means to be living, not to distinguish living and nonliving. Nonliving things often share some characteristics with living things (e.g., a fire uses energy and grows). Simply listing the characteristics that distinguish living things from nonliving things is not appropriate at this grade level. There are different kinds of living things. The focus is on familiar organisms (e.g., grass, trees, flowers, cats, dogs, horses). Some grade-appropriate characteristics include that living things grow, reproduce, require energy and respond to stimuli. Animals need food for energy; plants acquire energy from the sun. Living things respond to stimuli (e.g., fish in an aquarium respond to the addition of food). Living things grow (e.g., seedlings placed in soil grow). Conduct experiments and explorations to observe what happens when plants are placed in different classroom habitats (e.g., on the floor, in a closet, on a desk). Some observations can also be done virtually. When studying living things, ethical treatment of animals, safety procedures and proper hygiene must be employed. Respect for and proper treatment of living things must be modeled. For example, shaking a container, rapping on insect bottles, unclean cages or aquariums, leaving living things in the hot sun or exposure to extreme temperatures (hot or cold) must be avoided. The National Science Teachers Association (NSTA) has a position paper to provide guidance in the ethical use and treatment of animals in the classroom. **Future Application of Concepts** **Grades 1-2:** This content builds to understanding that living things use the environment to acquire what they need in order to survive. **Grades 3-5:** Food webs and food chains are used to illustrate energy transfer within an ecosystem. **Grades 6-8:** The characteristics of life are detailed via Modern Cell Theory and reproduction.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Nature investigations			
	Observe nature in a variety of ecosystems, multiple times a year. Record the different plants and animals found and patterns that emerge throughout the year. Design an investigation to document plant growth.	Draw or take pictures as a plant grows (e.g., draw pictures each day of a bud of a flowering plant to document its growth). Document and describe the living things found in an area.	Describe characteristics and traits of a living thing in the home or school habitat.
Classroom living organism			
Design a habitat that will support a classroom pet or plant. Provide for all its needs including, but not limited to food, water, air, shelter, cleanliness and safety.		Keep a classroom journal or graph documenting the growth of a plant or animal. Alternatives to a classroom pet could include webcams and visits to zoos or parks.	Describe how a chosen organism changes as it grows.
Living things grow and reproduce			
	Design an investigation, using student heights, a class pet or webcams, where students watch and document living things as they grow (e.g., find a webcam watching a nest or baby animals and, as a class, take sequential screenshots of the babies).	Create a collage of animals connecting adults and offspring. Create a class book of animals and their babies. **Note:** *Neither of these should focus on different life cycles.*	Explain that living things grow and reproduce.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	Characteristics of plants		
Design and plant a native pollinator garden. Make observations of the changes that occur. Observe what animals come to visit and make predictions about the purpose of their visits (e.g., food, shelter).	Design an investigation to observe how plants grow (e.g., bean seed on a paper towel or dampened cotton). • How does location affect plant growth? • Which direction do a plant's roots and leaves grow? • How will seeds grow after being turned upside down (e.g., after planting seeds in plastic baggies, let them sprout for a few days then turn half the baggies upside down to determine which direction the plants now grow)?	Draw pictures to document different plants' growth patterns. Use either classroom plants or a flower garden. Create a graph and document growth on a regular basis. Discuss and compare differences among plants.	Describe how a plant grows. Explain that a plant's stem and leaves grow toward the sun and its roots grow down.
	Living things are found all over the world		
	Explore the different types of plants and animals that are found around the world (e.g., visit local zoos, use worldwide webcams or computer sites like National Geographic Kids). Research different animals and plants to determine where they naturally live. Using results from the research, create a classroom map to illustrate that living things are found all over the world.	Create a class book for regions of the world and document what plants and animals can be found there.	Explain that living things can be found all over the world.

Kindergarten continued

LIFE SCIENCE (LS)

Topic: Physical and Behavioral Traits of Living Things
This topic focuses on observing, exploring, describing and comparing living things in Ohio.

CONTENT STATEMENT	CONTENT ELABORATION
K.LS.2: Living things have physical traits and behaviors, which influence their survival. Living things are made up of a variety of structures. Some traits can be observable structures. Some of these structures and behaviors influence their survival.	**Kindergarten Concepts** At this grade level, providing exposure through personal observation and stories to a large variety of living things is required. The focus is not on naming the structures of living things but associating through interaction and observation that living things are made of structures, and because of those structures, living things can do specific activities. Identify and discuss examples, such as: birds having wings for flying and beaks for eating; dogs having eyes for seeing, teeth for chewing and legs for moving; trees having leaves to capture sunlight and trunks for support. Concrete experiences are necessary to deepen knowledge of the traits and behaviors of living things. Technology can be used to compare data on the number of honeybees observed in the schoolyard with other schools. Additional inquiry investigations include conducting observations of pond water (focusing on macroscopic organisms), raising a classroom pet (check for student allergies), bird watching, noting differences between different types of plants and planting seeds and watching them grow. **Future Application of Concepts** **Grades 1-2:** The physical environment is identified as the source for what organisms need to survive. **Grades 3-5:** Plants and animals have certain physical or behavioral characteristics that improve their chances of surviving in specific environments. **Grades 6-8:** Changes in environmental conditions can affect how beneficial a trait will be for survival and reproductive success of an individual or an entire species.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Nature observations			
Design and create an animal-proof structure (e.g., raccoon proof garbage can, squirrel proof bird feeder).	Choose a focus for observation (e.g., trees, birds, insects). Take note of the physical structures of that living organism and discuss how those structures influence the organism's survival (e.g., wings for flight, placement of eyes, thorns).	Sort collections or drawings of organisms by similar structures. Discuss similarities with classmates. Compare the human heart with the heart shape. Explain what job the heart does. Explore the human sensory system including sight, touch, taste, smell and hearing. Identify the sensory organs and their functions. Identify ways each of these senses helps humans survive.	Give an example of a structure and tell how it helps an organism survive. Identify the major parts of the human body using appropriate names. Describe their functions.
Insect observations			
	Create a plate of food to attract insects. Take the plate outside and observe what types of insects are attracted. Observe the insects' structures and behaviors. Explore what happens if the plate contains different foods or is placed in a new location.	Observe and document body structure, behavior and numbers of insects visiting an insect food plate. Discuss questions such as: What do insects' bodies look like? How do they move and communicate?	Describe an insect's structure and behavior.
Bird observations			
	Place birdfeeders around the schoolyard with different types of seed/food in each. Observe which birds are attracted to each feeder. Observe the birds' structures and behaviors.	Observe and document body structure, behavior, and numbers of birds visiting a feeder. Discuss questions such as: How are the beaks of different birds similar or different? How do birds react to one another? Is the feeding behavior the same in different seasons?	Describe a bird's structure and behavior.

Grade 1

INTRODUCTION TO CONTENT STATEMENTS

GRADE BAND THEME: OBSERVATIONS OF THE ENVIRONMENT

This theme focuses on helping students develop the skills for systematic discovery to understand the science of the natural world around them in greater depth by using scientific inquiry.

STRANDS

Strand Connections: Energy is observed through movement, heating, cooling and the needs of living organisms.

EARTH AND SPACE SCIENCE (ESS)	PHYSICAL SCIENCE (PS)	LIFE SCIENCE (LS)
Topic: Sun, Energy and Weather This topic focuses on the sun as a source of energy and energy changes that occur to land, air and water.	**Topic: Motion and Materials** This topic focuses on the changes in properties that occur in objects and materials. Changes of position of an object are a result of pushing or pulling.	**Topic: Basic Needs of Living Things** This topic focuses on the physical needs of living things in Ohio. Energy from the sun or food, nutrients, water, shelter and air are some of the physical needs of living things.
CONDENSED CONTENT STATEMENTS		
1.ESS.1: The sun is the principal source of energy. **1.ESS.2:** Water on Earth is present in many forms.	**1.PS.1:** Properties of objects and materials can change. **1.PS.2:** Objects can be moved in a variety of ways, such as straight, zigzag, circular and back and forth.	**1.LS.1** Living things have basic needs, which are met by obtaining materials from the physical environment. **1.LS.2:** Living things survive only in environments that meet their needs.

NATURE OF SCIENCE GRADES K-2

Nature of Science One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.	
Categories	**K-2**
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Apply knowledge of science content to real-world challenges. • Plan and conduct simple scientific investigations using appropriate safety techniques based on explorations, observations and questions. • Employ simple equipment and tools to gather data and extend the senses. • Use data and mathematical thinking to construct reasonable explanations. • Communicate with others about investigations and data.
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Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• Everyone explores the world which generates questions. • The answer is not always as important as the process. • Questions often lead to other questions. • Discoveries are communicated and discussed with others. • People address questions through collaboration with peers and continued exploration. • Everyone can see themselves as scientists.
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Grade 1 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Sun, Energy, and Weather
This topic focuses on the sun as a source of energy and energy changes that occur to land, air and water.

CONTENT STATEMENT	CONTENT ELABORATION
1.ESS.1: The sun is the principal source of energy Sunlight warms Earth's land, air and water. The amount of exposure to sunlight affects the amount of warming or cooling of air, water and land.	**Prior Concepts Related to Sun and Weather** **PreK-K:** Weather changes every day. Weather changes are short- and long-term. The sun is visible during the day and the apparent position of the sun can change. **Grade 1 Concepts** Quantitative measurements are used to observe and document the warming and cooling of air, water or soil. The length of time an object or material (including water) is exposed to sunlight and its resulting temperature can be observed, as should the amount of time for the object or material to cool down after it is taken out of the sunlight. Appropriate tools and technology are used to collect, compare and document data. Investigation and experimentation are combined with explanation, questioning and discussion of the results and findings. **Future Application of Concepts** **Grade 2:** The relationship between energy and long- and short-term weather is introduced. **Grades 3-5:** Renewable energy, forms of energy (e.g., heat, light, electrical energy), the solar system and patterns/cycles between Earth and the sun are explored.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Energy from the sun			
Design a structure that will warm soil, water or air (e.g., black paper, funnel shapes, tinfoil). Design a structure that will cool soil, water or air (e.g., create a way to shade the soil, water, air). Design and create a structure that will decrease or increase the rate at which an ice cube melts.	Place cups of soil and water in different areas. Take temperature readings at different times during the day. Demonstrate that energy from the sun heats the soil, water and air. Natural sunlight is preferred over alternate sources such as a lamp in this demonstration. Collect data (e.g., temperature, water, outside weather, amount of daily sunlight) and organize to use in the comparison. Place frozen water in the sun. Periodically measure the temperature and the thawing of the water. Chart the time, temperature and water state. Discuss possible reasons for the change.	Solar energy affects temperature. Measure temperature changes of soil, water and air in different settings and/ or exposures to sunlight. Make a graph, chart or table to record and organize the data.	Identify the sun as a primary source of energy.
Solar device			
Build a device that can collect or use solar energy (e.g., solar oven, solar wind chimes, solar water heating device).	Investigate how different materials absorb or reflect sunlight. Investigate what colors or materials work best, where the device works best and how the device can be changed to work better.		Describe how sunlight affects the heating of objects.
Cold frame			
Make a mini cold frame that can be used to protect plants from cold temperatures. Use recyclable materials, such as plastic bottles, milk jugs or cartons.	Evaluate the placement of a cold frame to get the most autumn/winter sunlight. Compare the results within the class or from class to class. Collect data (e.g., temperature, water, outside weather, amount of daily sunlight) and organize to use in the comparison.		Recognize that sunlight warms water, air and soil.

Grade 1 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Sun, Energy, and Weather
This topic focuses on the sun as a source of energy and energy changes that occur to land, air and water.

CONTENT STATEMENT	CONTENT ELABORATION
1.ESS.2: Water on Earth is present in many forms. The physical properties of water can change. These changes occur due to changing energy. Water can change from a liquid to a solid and from a solid to a liquid. **Note**: *Water as a vapor is not introduced until grade 2; the water cycle is reserved for later grades.*	**Prior Concepts Related to Water** **PreK-K:** Water can be observed in many different forms. Precipitation (e.g., rain, sleet, hail, snow) is a component of weather that can be measured. **Grade 1 Concepts** Water can be observed in lakes, ponds, streams, wetlands, the ocean and through weather events. Freezing and melting of water are investigated through measurements and observations using technology, in the classroom or in a natural setting. Examining maps of Ohio, world maps or globes can illustrate the amount of Earth's surface that is covered in water and why it is important to learn about water. Water can change the shape of the land (e.g., moving soil or sand along the banks of a river or at the beach). Water can also be observed in the air as clouds, steam or fog, but this content should be limited to observation only at this grade level. Investigations (inside or outside) and experimentation are used to demonstrate the changing properties of water. Use appropriate tools to test and measure water's weight, texture, temperature or size (e.g., compare measurements of water before and after freezing, examine the texture of snow or ice crystals using a hand lens) to document the physical properties. **Future Application of Concepts** **Grade 2:** Water as a vapor is introduced. Water is present in the atmosphere. **Grades 3-5:** Water is identified as a non-living resource that can be used for energy. Common states of matter include liquids, solids and gases. Earth's surface has been changed by processes involving water.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	Water on Earth		
	Investigate what happens to water as it freezes and thaws. Collect measurements, take temperature readings and record the length of time to freeze or thaw. Ask: What could happen when liquid water gets into rocks and then freezes? Design investigations to demonstrate how varying amounts of water affect the shape of the land. Spritzing, dripping, and pouring could simulate different amounts of rain. Freeze the different samples to demonstrate the effects of freezing and thawing and how that changes the shape of the land. Extend to show the effects using different items for the land (e.g., sand, soil, gravel). Investigate the physical differences (e.g., weight, temperature, texture) between snow or crushed ice and liquid water Ask: How much does one cup of snow/crushed ice/liquid water weigh? How does snow/crushed ice look through a hand lens? Discuss how these findings can apply to weather observations (e.g., how many inches of snow equal one inch of rain?).	Examine maps, globes, models and discuss the amount of land vs. water. Identify water that is solid (ice) and water that is liquid. Collect temperature readings during precipitation events. Make a graph, chart or table to compare the temperatures during rainfall, snow or sleet. Discuss the patterns that are observed.	Identify the different areas where water can be observed (e.g., lakes, streams, ponds, oceans, rain, snow, hail, sleet, fog). Explain that heating and cooling water can change it from a solid to a liquid or a liquid to a solid. Explain some ways that water can affect the land.

Grade 1 continued

PHYSICAL SCIENCE (PS)

Topic: Motion and Materials
This topic focuses on the changes in properties that occur in objects and materials. Changes of position of an object are a result of pushing or pulling.

CONTENT STATEMENT	CONTENT ELABORATION
1.PS.1: Properties of objects and materials can change. Objects and materials change when exposed to various conditions, such as heating or cooling. Changes in temperature are a result of changes in energy. Not all materials change in the same way.	**Prior Concepts Related to Properties of Objects and Materials** **PreK-K:** Objects are things that can be seen or felt. Properties can be observed using tools or one's senses and can be used to sort objects. Comparisons of objects are made as a precursor to measurement. **Grade 1 Concepts** Materials can be exposed to conditions that change some of their properties, but not all materials respond the same way. The properties of a material can change as it interacts with other materials. Heating and cooling changes some, but not all, properties of materials. Emphasis is placed on observations. Concepts of thermal energy, atoms and heat transfer are not appropriate at this grade level. Some materials are a liquid or solid at room temperature and may change from one form to the other with a change in temperature. A liquid may turn into a solid when cooled. A solid may turn into a liquid when heated. The amount of the material in the solid or liquid remains the same before and after the change. Investigations and experiments (may include virtual investigations) are conducted to explore property changes of objects and materials. **Future Application of Concepts** **Grade 2:** Water can change from liquid to vapor in the air and from vapor to liquid (ESS). **Grades 3-5:** Matter is defined. Measurements of weight and liquid volume are made. Properties of solids, liquids and gases and phase changes are explored. During any change, including phase changes, the total mass remains constant. The sum of the mass of the parts of an object is equal to the mass of the entire object.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students with opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	Solids and liquids		
Design and create a device to increase the rate that a substance melts.	Design an investigation to change a solid into a liquid and back to a solid (e.g., ice to water, popsicle to liquid, melting chocolate chips). Weigh the substance before and after melting to demonstrate the amount does not change, just the shape. Include temperature readings to demonstrate that heat energy caused the change. Investigate what happens to a solid when heat energy is added (e.g., crayon and a blow dryer).	Document and describe properties of a solid (e.g. composition, texture, shape). Document and describe properties of a liquid (e.g. composition, texture, shape). Compare the properties of solids and liquids. Describe changes to the shapes of solids or liquids as you place them into different containers, melt or freeze them. Create a graphic to depict the changes of a solid to a liquid.	Explain what causes properties of objects and materials to change. Explain the properties of solids and liquids.
	Changes in properties		
	Plan and implement an investigation to test various clay shapes (e.g., a clay ball, a clay block, flattened clay with edges) to determine how shape affects the ability of a material to float or sink in water. Design an investigation to see how observable properties of solids can change (e.g., tearing, wetting, cutting, pressure application).	Create a graphic to illustrate changes of a material as it changes.	Classify various types of changes that objects or materials can go through to change observable properties (e.g., freezing, melting, tearing, wetting).

Grade 1 continued

PHYSICAL SCIENCE (PS)

Topic: Motion and Materials
This topic focuses on the changes in properties that occur in objects and materials. Changes of position of an object are a result of pushing or pulling.

CONTENT STATEMENT	CONTENT ELABORATION
1.PS.2: Objects can be moved in a variety of ways, such as straight, zigzag, circular and back and forth. The position of an object can be described by locating it relative to another object or to the object's surroundings. An object is in motion when its position is changing. The motion of an object can be affected by pushing or pulling. A push or pull is a force that can make an object move faster, slower or go in a different direction. Changes in motion are a result of changes in energy.	**Prior Concepts Related to Motion** **PreK-K:** Vibrating objects can cause sound. **Grade 1 Concepts** The position of an object is described by comparing its location relative to another object (e.g., in front, behind, above, below). Objects can be moved and their positions changed. Objects can move in a straight line (e.g., a dropped coin falling to the ground) or a circle (e.g., a pinwheel) or back and forth (e.g., a swing) or even in a zigzag pattern. Objects near Earth fall to the ground unless something holds them from falling. Object motion can be faster, slower or change direction by pushing or pulling the object. Experimentation, testing and investigations of different ways to change the motion of different objects (e.g., a ball, a pinwheel, a kite) can be used to demonstrate movement. Force is a push or pull between two objects and energy is the property of an object that can cause change. A force acting on an object can sometimes result in a change in energy. The differences between force and energy will be developed over time and are not appropriate for this grade level. **Note:** *Scientific definitions and calculations of speed are not appropriate at this grade level*. **Future Application of Concepts** **Grade 2:** Forces are necessary to change the motion of objects**.** **Grades 3-5:** The amount of change in movement of an object is based on the mass of the object and the amount of force exerted.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Zig-zag maze			
Design, construct and test a device that will cause a ping-pong ball to move in a zigzag pattern. Test and evaluate the effectiveness of different devices made by different groups in the class. Redesign the device for greater effectiveness.	Create an investigation with a ball (e.g., ping-pong ball, marble) to demonstrate different paths of motion in a zig-zag pattern.	Explain how the position of the ball changed in a device that causes a ball to move in a zig-zag pattern.	Explain what causes a ball to change the path of its motion.
Ways to change the motion of an object			
	Implement a scientific investigation to determine how a ball can be made to speed up, slow down or change direction. With the class, list all the ways that were found.	Compare the different methods used by different groups in the class.	Illustrate that a push or pull is needed to speed up, slow down or change the direction of a moving object.
Toys			
	Design and create an investigation to discover different paths of motion toys will take.	Sort and chart a variety of toys by their different paths of motion. Represent the different motions of a toy in words, pictures and diagrams.	Describe different paths of motion (e.g., circular, straight, zig-zag).
Playground			
Design and create a model of playground equipment that requires a push or pull to work.		Explain how a piece of playground equipment works (push or pull). Explore playground equipment and categorize those that use a push, a pull or both. Explain the motion and forces (e.g., push or pull) needed to play on a piece of playground equipment.	Identify an object's position with respect to another object.

Grade 1 continued

LIFE SCIENCE (LS)

Topic: Basic Needs of Living Things
This topic focuses on the physical needs of living things in Ohio. Energy from the sun or food, nutrients, water, shelter and air are some of the physical needs of living things.

CONTENT STATEMENT

1.LS.1: Living things have basic needs, which are met by obtaining materials from the physical environment.

Living things require energy, water, and a particular range of temperatures in their environments. Plants get energy from sunlight. Animals get energy from plants and other animals. Living things acquire resources from the living and nonliving components of the environment.

CONTENT ELABORATION

Prior Concepts Related to Interactions within Environments
PreK-K: Living things are identified in a variety of ecosystems. Living things have physical traits, which enable them to live in different ecosystems.

Grade 1 Concepts
Earth has many different environmental conditions that support living things. The emphasis of this content statement is that living things meet their basic needs for survival by obtaining necessary materials from the environment. This includes, but is not limited to, temperature range, amount of water, amount of sunlight and available food sources. The environment includes both living (plants and animals) and nonliving (e.g., water, air, sunlight, nutrients) things.

Living things get the energy they require to respond, grow and reproduce from the environment. Observing energy being used in everyday situations can help promote understanding that living things get resources from the physical environment. A detailed discussion of energy is not appropriate at this grade level. Energy is not scientifically explained until grade 3.

When studying living things, ethical treatment of animals and safety must be employed. Respect for and proper treatment of living things must be modeled. For example, shaking a container, rapping on insect bottles, unclean cages or aquariums, leaving living things in the hot sun or exposure to extreme temperatures (hot or cold) must be avoided. The National Science Teachers Association (NSTA) has a position paper to provide guidance in the ethical use and treatment of animals in the classroom. Investigations about the types of living things that live in specific ecosystems can be done virtually or in nature.

Future Application of Concepts
Grade 2: How living things impact the environment and how the environment impacts living things will be examined.

Grade 3-5: Life cycles of plants and animals will be explored.

Grades 6-8: Changes in environmental conditions can affect how beneficial a trait will be for survival and reproductive success of an individual or an entire species.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Bird feeders			
Design a bird feeder and blend of birdseed that will attract the most birds of one kind or the greatest variety of birds. Share designs, results and recommendations with an authentic audience. Compare the feeder usage at different times of the year.	Plan and implement a classroom investigation that answers the question: *Does the type of food influence what type of birds will come to a bird feeder?*	Based on observations of birds in the field, compare the food choices of birds and create a chart to communicate findings.	
Seasonal nature walks or explorations			
	Make observations outside at least once each season to discover what living things are in an area. Look to see what other things are there that meet the needs of the organisms (e.g., berries on trees, bushes for birds, water source). Compare what is found in various seasons.	Record observations from nature walks (e.g., photos, drawings, journals). Have groups share and discuss findings. Compare with prior explorations of the same area. Compare the ways humans get air, water and food with those of other living things. Include plants and animals that are found in the local community or a given ecosystem.	Identify the basic survival needs of plants and animals (e.g., classroom pets, plants used in classroom experiments, organism observed in nature).

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Ohio wildflower garden			
Research and plant a native wildflower garden to attract birds, butterflies, bees and/or moths.	Seasonally, observe a wildflower garden paying close attention to what animals are attracted to the garden. Record the interactions observed.	Create a pamphlet of which birds, butterflies or moths are attracted to which plants.	Identify what plants, birds, bees and moths need to survive. Explain how those needs are met by the environment.
Classroom habitat exploration			
	Use a terrarium or aquarium to study interactions between organisms. Observe how organisms change throughout the year. Document the changes with photos, drawings or measurements.	Graph plant and animal growth in a classroom habitat. Draw and explain interactions between plants and animals.	Explain that plants get energy from the sun and animals get energy from plants or other animals.

Grade 1 continued

LIFE SCIENCE (LS)

Topic: Basic Needs of Living Things
This topic focuses on the physical needs of living things in Ohio. Energy from the sun or food, nutrients, water, shelter and air are some of the physical needs of living things.

CONTENT STATEMENT	CONTENT ELABORATION
1.LS.2: Living things survive only in environments that meet their needs. Resources are necessary to meet the needs of an individual and populations of individuals. Living things interact with their physical environments as they meet those needs. Effects of seasonal changes within the local environment directly impact the availability of resources.	**Prior Concepts Related to Interactions within Environments** **PreK-K:** Living things are identified in a variety of ecosystems. Living things have physical traits, which enable them to live in different ecosystems. **Grade 1 Concepts** Plants and animals require resources from the environment. The focus at this grade level is on macroscopic interactions and needs of common living things (plants and animals). Animals require basic habitat components, including food, water, cover and space. The amount and distribution of the basic components will influence the types of animals that can survive in an area. Food sources might include plants, fruits, seeds, insects or other animals. Water sources may be as small as drops of dew found on grass or as large as a lake or river. Animals need cover for many life functions including nesting, escaping from predators, seeking shelter from unfavorable weather conditions and resting. Animals also need space in which to perform necessary activities such as feeding or raising young. Seasonal changes affect the resources available to living things (e.g., grasses are not as available in winter as they are in summer). The needs of plants include room to grow, appropriate temperature range, light, water, air and nutrients. Changes in these conditions can affect the growing season for certain plants. The amount and distribution of these conditions will influence the types of plants that can survive in an area. Observations of seasonal changes in temperature, liquid water availability, wind and light are applied to the effect of seasonal changes on local plants. **Future Application of Concepts** **Grade 2:** This concept expands to include interactions between organisms and the physical environment as the environment changes. **Grade 3-5:** The fact that organisms have life cycles that are part of their adaptations for survival in their natural environment builds upon this concept. **Grades 6-8:** In any particular biome, the number, growth and survival of organisms and populations depend on biotic and abiotic factors.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	Environmental explorations		
Design an ideal habitat for a human. Identify ways human needs (e.g., water, shelter, air, space, food) are met by the habitat. Make drawings, descriptions or models of the habitat.	Go on an outside habitat exploration. What is in the habitat that meets the needs of both plants and animals? Make sure to include water sources and food sources (including sunlight for plants). Look for signs of nesting, places for animals to hide and places for animals to raise their young. Repeat the observations throughout different seasons and make comparisons. Visit different local or virtual habitats and compare the living things in the habitats. Multiple habitats could include one by a water source, a farm and/or the school ground. If possible, visit multiple times a year.	Create a graphic comparing the living things found in various habitats and during different seasons. Identify what habitat components humans need to survive. Compare different habitats and choose the best habitat for humans to survive in.	Explain how habitats meet the needs of a variety of plants and animals. Explain what an animal needs to survive in its habitat. Explain how seasons affect plants and animals. Explain how senses help humans survive in their habitat.
	Plant investigations		
	Design investigations to discover what a plant needs to grow and survive. Change only one variable per plant group. Compare plants in the sun and plants in the dark; compare plants that are watered and ones that are not; compare seeds in soil and seeds that are not.	For the plant investigations, create a poster or journal entry demonstrating the differences in the plant growth.	Explain what a plant needs to survive in its habitat.

Grade 2

INTRODUCTION TO CONTENT STATEMENTS

GRADE BAND THEME: OBSERVATIONS OF THE ENVIRONMENT

This theme focuses on helping students develop the skills for systematic discovery to understand the science of the natural world around them in greater depth by using scientific inquiry.

STRANDS

Strand Connections: Living and nonliving things may move. A moving object has energy. Air moving is wind and wind can make a windmill turn. Changes in energy and movement can cause change to organisms and the environments in which they live.

EARTH AND SPACE SCIENCE (ESS)	PHYSICAL SCIENCE (PS)	LIFE SCIENCE (LS)
Topic: The Atmosphere This topic focuses on air and water as they relate to weather and weather changes that can be observed and measured.	**Topic: Changes in Motion** This topic focuses on observing the relationship between forces and motion.	**Topic: Interactions within Habitats** This topic focuses on how ecosystems work by observations of simple interactions between the biotic/living and abiotic/nonliving parts of an ecosystem. Just as living things impact the environment in which they live, the environment impacts living things.
CONDENSED CONTENT STATEMENTS		
2.ESS.1: The atmosphere is primarily made up of air. **2.ESS.2:** Water is present in the atmosphere. **2.ESS.3:** Long- and short-term weather changes occur due to changes in energy.	**2.PS.1:** Forces change the motion of an object.	**2.LS.1:** Living things cause changes on Earth. **2.LS.2:** All organisms alive today result from their ancestors, some of which may be extinct. Not all kinds of organisms that lived in the past are represented by living organisms today.

NATURE OF SCIENCE GRADES K-2

Nature of Science
One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.

Categories	K-2
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Apply knowledge of science content to real-world challenges. • Plan and conduct simple scientific investigations using appropriate safety techniques based on explorations, observations and questions. • Employ simple equipment and tools to gather data and extend the senses. • Use data and mathematical thinking to construct reasonable explanations. • Communicate with others about investigations and data.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past, and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	• The world is discovered through exploration. • Exploration leads to observation. Observation leads to questions. • Natural events happen today as they happened in the past. • Events happen in regular patterns and cycles in the natural world.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• Everyone explores the world which generates questions. • The answer is not always as important as the process. • Questions often lead to other questions. • Discoveries are communicated and discussed with others. • People address questions through collaboration with peers and continued exploration. • Everyone can see themselves as scientists.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• It is essential to learn how to identify credible scientific evidence. • Ideas are revised based on new, credible scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Complete *Nature of Science* document is found on pages 8-12.

Grade 2 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: The Atmosphere
This topic focuses on air and water as they relate to weather and weather changes that can be observed and measured.

CONTENT STATEMENT	CONTENT ELABORATION
2.ESS.1: The atmosphere is primarily made up of air. Air has properties that can be observed and measured. The transfer of energy in the atmosphere causes air movement, which is felt as wind. Wind speed and direction can be measured.	**Prior Concepts Related to Air and Atmosphere** **PreK-1:** The term energy is introduced in grade 1. Wind is air in motion. Air is a nonliving substance that surrounds Earth. Wind can be measured and sunlight warms the air. **Grade 2 Concepts** In the earlier grades, wind is measured but not with a numerical value or directional data (e.g., wind may be moving faster/slower than yesterday and is coming from a different direction). Wind can change the shape of the land (e.g., sand dunes, rock formations). In grade 2, wind is measured with a numeric value and direction (e.g., wind speed is 6 mph, wind direction is west to east). Air takes up space (volume) and has mass (differentiating between mass and weight is not necessary at this grade level). Heating and cooling of air (transfer of energy) results in movement of air (wind). The direction and speed of wind and the air temperature can be measured using a variety of instruments, such as windsocks, weather vanes, thermometers or simple anemometers. Weather events that are related to wind (e.g., tornadoes, hurricanes) are included in this content. Monitoring weather changes using technology (e.g., posting/sharing classroom data with other classes at the school or at other schools) can lead to review and questioning of data and evaluation of wind patterns that may be documented. Experiments, models (including digital/virtual) and investigations are conducted to demonstrate the properties of air, wind and wind-related weather events. Questions, comparisons and discussions related to actual data and the analysis of the data is an important way to deepen the content knowledge. **Future Application of Concepts** **Grades 3-5:** Renewable energy and air pollution are studied. Wind can weather and erode Earth's surface. **Grades 6-8:** Thermal energy transfers in the atmosphere, causing air currents and global climate patterns.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Create an instrument to measure wind			
Design and construct an instrument that can measure wind speed and wind direction. Properties of the chosen materials and design should be evaluated as part of the testing and decision-making process. Demonstrate the final product to the class.	Take measurements of wind speed and wind direction each day for two weeks. Record the measurements and plot results on a graph. Find and interpret wind patterns (e.g., when the wind comes from the south the speed is lower than when the wind comes from the north).		Explain how an anemometer measures wind speed.
Air activities			
Design and construct a way to lift an object using air (e.g., plastic bags and straws). Journal or use technology to document the design trials and results.		Create a demonstration to show that air has mass and takes up space (has volume).	Describe the properties of air.

Grade 2 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: The Atmosphere
This topic focuses on air and water as they relate to weather and weather changes that can be observed and measured.

CONTENT STATEMENT	CONTENT ELABORATION
2.ESS.2: Water is present in the atmosphere. Water is present in the atmosphere as water vapor. When water vapor in the atmosphere cools, it forms clouds, fog, rain, ice, snow, sleet or hail. **Note**: *The emphasis at this grade level is investigating condensation and evaporation, not memorizing the water cycle itself.* **Note**: *The emphasis is not in naming cloud types, but in relating the characteristics of the clouds with weather.*	**Prior Concepts Related to Water in the Atmosphere** **PreK-1:** The term energy is introduced in grade 1. Wind and water are observable parts of weather. Sunlight warms water and air. The physical properties of water can change (liquid to solid and solid to liquid). **Grade 2 Concepts** The physical properties of water (from grade 1) are expanded to include water vapor (water in the air). The different states of water are observed in weather events, nature and/or classroom investigations. The concepts of condensation and evaporation are explored through experimentation and observation. The different parts of the water cycle are explored and discussed. The focus is on investigation and understanding, not on vocabulary. Water can change from liquid to vapor and from vapor to liquid. When water in the atmosphere cools because of a change in energy, it often forms small droplets of liquid water or ice that can be seen as clouds. The small water droplets can then form raindrops. Water droplets can change to solid by freezing into snow, sleet or hail. Cloud formation and types of clouds are introduced as they relate to weather. Clouds are moved by wind. Factors such as water contamination/pollution can be introduced within this content statement as they relate to pollutants that can enter waterways through precipitation, evaporation and condensation. Experiments and investigations that demonstrate the conditions required for condensation or evaporation to occur lead to a deeper understanding of these concepts. Appropriate tools and technology can be used to observe, share results or document data. Relating the required conditions to actual weather observations, collecting and documenting data, drawing conclusions from the data and discussions about the findings are included for this content statement. **Future Application of Concepts** **Grades 3-5:** The states and conservation of matter, weathering and erosion of Earth's surface, seasonal changes and energy transfer are explored. **Grades 6-8:** The hydrologic cycle, transfer of energy among the atmosphere, hydrosphere and lithosphere and biogeochemical cycles are studied.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Condensation and evaporation			
Design a device to collect water from the atmosphere (i.e. collect condensation).	Plan and implement an investigation to explore the factors that contribute to water evaporating into the atmosphere. Generate a list of all the methods that were tested and discuss the different results with the class. Plan and implement an investigation to explore what happens when pollution is in a body of water that evaporates. Use a simple model that utilizes sediment, vinegar or vegetable oil as a contaminant.		Recall that water can change from liquid to vapor and/or vapor to liquid.
Clouds			
	Document observations over a period of time to find if there is a relationship between the characteristics of the clouds (e.g., shapes, sizes, color, sky coverage) and the weather (e.g., storms, precipitation types and/or amounts).		List the various forms of water that can be found in the atmosphere (e.g., clouds, steam, fog, snow, sleet, hail).

Grade 2 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: The Atmosphere

This topic focuses on air and water as they relate to weather and weather changes that can be observed and measured.

CONTENT STATEMENT	CONTENT ELABORATION
2.ESS.3: Long- and short-term weather changes occur due to changes in energy. Changes in energy affect all aspects of weather, including temperature, precipitation, and wind.	**Prior Concepts Related to Water in the Atmosphere** **PreK-1:** The term energy is introduced in grade 1. Weather changes during the day and from day to day. Weather changes can be long- or short-term. Weather changes can be measured and have patterns. **Grade 2 Concepts** Weather is a result of energy change. Heating (from sunlight) and cooling of water, air and land are directly related to wind, evaporation, condensation, freezing, thawing and precipitation. Density and convection should not be introduced at this grade level. Weather patterns (long-term) and fronts (short-term) can be documented through consistent measuring of temperature, air pressure, wind speed and direction, and precipitation. Some forms of severe weather can occur in specific regions/areas, scientists forecast severe weather events. Weather data can be measured, collected and documented over a period of time and then connected to observable forms of energy (e.g., wind causes a sailboat to move, the sun can heat the sidewalk). Experiments and investigations (both inside and outside of the classroom) are used to demonstrate the connection between weather and energy. Discussion of energy at this grade level should be limited to observable changes. **Future Application of Concepts** **Grades 3-5:** Changes in energy and changing states of matter are explored in greater depth through applications other than weather. Renewable resources (energy sources) and changes in Earth's environment through time are examined. **Grades 6-8:** Changes of state are explained by molecules in motion, kinetic and potential energy. The hydrologic cycle and thermal energy transfers among the hydrosphere, lithosphere, and atmosphere are studied.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Weather			
Use wind-chill data to develop a school-wide recess policy based on wind-chill limits.	Plan and implement an investigation to determine the factors or characteristics that contribute to the changes in day-to-day weather (storms, fronts). Compare average annual temperatures between cites at the same latitude, but at different elevations or proximity to large lakes or the ocean. Plan and implement an investigation to collect and measure wind-chill data (or data that calculates the "feels like" temperature in the summer by relating humidity levels and temperature). Compare local results with a different location in the U.S. and discuss the similarities/differences of the data and the possible reasons for the similarities and differences.	Research the long-term or short-term changes in weather that occur at specific weather fronts (e.g., ask: What happens when warm, moist air collides with cold, dry air?) Represent the findings graphically or present findings to the class. Based on student collected data, outline the relationship between wind and cloud changes vs. changes in weather from one season to another season. Outline relationships in writing or through a class discussion, oral presentation or graphic representation.	Recognize that a weather front is an area where different air masses collide. Recall that weather changes occur due to energy changes.

Grade 2 continued

PHYSICAL SCIENCE (PS)

Topic: Changes in Motion
This topic focuses on observing the relationship between forces and motion.

CONTENT STATEMENT	CONTENT ELABORATION
2.PS.1: Forces change the motion of an object. Motion can increase, change direction or stop depending on the force applied. The change in motion of an object is related to the size of the force. Some forces act without touching, such as using a magnet to move an object or objects falling to the ground.	**Prior Concepts Related to Forces and Motion** **PreK-1:** Vibrating objects are observed producing sound. Motion is described as a change in an object's position. Forces are pushes and pulls that can change the motion of objects. **Grade 2 Concepts** Forces are needed to change the movement of an object by speeding up, slowing down, stopping or changing direction. Some forces act when an object is in contact with another object (e.g., physically pushing or pulling). Other forces act when objects are not in contact with each other (e.g., magnetic, gravitational, electrical). Gravitational, static electrical and magnetic forces are introduced through observation and experimentation only. The definitions of these forces should not be the focus of instruction. Earth's gravity pulls any object toward it, without touching the object. Static electricity also can pull or push objects without touching the object. Magnets can pull some objects to them (attraction) or push objects away from them (repulsion). Gravity, static electricity and magnets can be explored through experimentation, testing and investigation at this grade level. For a particular object, larger forces cause larger changes in motion. A strong kick to a rock is able to cause more change in motion than a weak kick to the same rock. Real-world experiences and investigations are used for this concept. There often is confusion between the concepts of force and energy. Force can be thought of as a push or pull between two objects and energy as the property of an object that can cause change. A force acting on an object can sometimes result in a change in energy. The difference between force and energy will be developed over time and is not appropriate at this grade level. **Note***: Introducing fields, protons, electrons or mathematical manipulations of positive and negative to explain observed phenomena is not appropriate at this grade level.* **Future Application of Concepts** **Grades 3-5:** The amount of change in movement of an object depends on the mass of the object and the amount of force exerted. **Grades 6-8:** Speed is defined and calculated. The field concept for forces at a distance is introduced.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Forces and motion			
	Predict the changes in motion that a moving object or an object at rest experiences when acted on by a force (e.g., push, pull, gravity).	Compare what is needed to get stationary objects moving and what is needed to get moving objects to stop.	Identify contact/noncontact forces that affect motion of an object (e.g., gravity, magnetic force, contact force). Recognize that greater changes in the motion of an object require larger forces.
Gravity			
	Explore the effects some very massive objects have on others even when the two objects might not touch (e.g., explore falling objects). Identify Earth as the object exerting the force of gravity on the falling objects.		Illustrate the effects of gravity through writing or pictures.
Magnets: pulling			
Design and construct a device to move an item from one position to another without touching (e.g., a metal matchbox car and magnet). Test the device and evaluate the design. If necessary, redesign the device until it can accomplish the task.	Explore the effects some objects have on others even when the two objects might not touch (e.g., experiment with different types and strength of magnets). Determine ways to vary the motion of the objects.	Pictorially represent the design of the device designed to move an object from one position to another without touching. Compare class designs and their effectiveness.	Identify a noncontact force that can affect the motion of an object (e.g., magnetic force, static electrical force, gravitational force).

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	Magnets: poles		
Use the polarity of a magnet to accomplish a task. Use magnets to create a game.	Explore a variety of magnets to discover poles (e.g., create floating rings with donut magnets and a pencil, observe the interaction of two bar magnets, use iron filings around various magnets).		Through writing and/or pictures represent orientations of magnets that will attract (pull) and repel (push).
	Static electricity		
	Explore the effects charged objects can have on other objects even when the two objects might not touch (e.g., experiment with a balloon rubbed on hair and pieces of paper).		
	Seat belts		
Design a seat belt to protect dogs or other service animals when in a car.	Design an investigation using a large toy car, ramp, doll and tape to represent how seat belts provide protection in a moving car.	Write a letter to a local government official persuading them to recommend laws to keep pets safe in cars based on seatbelt data from an investigation.	Explain how the size of a force can impact motion.
	Amusement rides		
Design and construct an amusement park ride that will keep a rider safe while speeding up, slowing down, changing direction and/or stopping.	Explore ways to change how something is moving (e.g., speeding up, slowing down, changing direction, stopping).	Draw an amusement ride. Label where the ride speeds up, slows down or changes direction.	Give two examples of how a force is applied in an amusement ride.

Grade 2 continued

LIFE SCIENCE (LS)

Topic: Interactions within Habitats
This topic focuses on how ecosystems work by observations of simple interactions between the biotic/living and abiotic/nonliving parts of an ecosystem. Just as living things impact the environment in which they live, the environment impacts living things.

CONTENT STATEMENT	CONTENT ELABORATION
2.LS.1: Living things cause changes on Earth. Living things function and interact with their physical environments. Living things cause changes in the environments where they live; the changes can be very noticeable or slightly noticeable, fast or slow. **Note:** *At this grade level, discussion is limited to changes that can be easily observed.*	**Prior Concepts Related to Interactions within Environments** **PreK-1:** Macroscopic characteristics of living things are observed, including basic survival needs of living things, how living things get resources from the environment and how available resources vary throughout the course of a year. **Grade 2 Concepts** The environment is a combination of the interactions between living and non-living components. Living things can cause changes in their ecosystems, which can be observed. These interactions can cause changes in groups of living things and the physical environment (e.g., soil, rocks, water). Conducting investigations (in nature or virtually) to document specific changes in the ecosystem, as well as the results of those changes, are used to demonstrate this concept (e.g., moles tunneling in a lawn, beavers or muskrats building dams, plants growing in cracks of rocks). Maps or charts can be used to document the location of specific types of living things found in the local area. The impact and actions of living things are investigated and explored. The focus is not limited to human interaction with the environment (such as resource use or recycling) and includes activities such as observing earthworm compost bins, ant farms and weeds growing on vacant lots. **Future Application of Concepts** **Grades 3-5:** Changes that occur in an ecosystem can sometimes be beneficial and sometimes harmful. **Grades 6-8:** Matter is transferred constantly from one organism to another and between organisms and their physical environment.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	**Demonstrating science knowledge**	**Interpreting and communicating science concepts**	**Recalling accurate science**
2.LS.1: Living things cause changes on Earth			
Design and build (with teacher help) a working worm composting bin or ant farm (whichever is most appropriate for the classroom) that can be used to observe the actions of the worms or ants. The project selected should be built on student ideas and not from a readymade kit.	Plan and conduct an investigation that will compare identical soil samples, one with earthworms and one without earthworms, over an extended period of time. Include data about temperature, amount of moisture, appearance, materials added, materials removed and/or odor. **Note:** *For this grade level, the presence of bacteria and fungi in soil are not included. Students may be able to see fungi fruiting bodies but would not be able to see the fungal cells without using tools and content knowledge that are above this grade level.*	Take a nature walk around the school on a weekly basis to make observations of changes in the ecosystem. Document through pictures or drawings. Look for human impact versus nature (e.g., breaking up a sidewalk due to tree roots, weeds growing through the sidewalk or blacktop). Represent data obtained from classroom investigations or real-world examples in a chart, table or pictograph (e.g., make a table of data obtained from soil samples with earthworms that compares them to soil samples without earthworms).	Recognize scientifically accurate facts in stories about environmental changes caused by living things. Identify ways humans have changed the Earth to provide food and energy for our bodies (e.g. farming, mining, creating dams).

Grade 2 continued

LIFE SCIENCE (LS)

Topic: Interactions within Habitats
This topic focuses on how ecosystems work by observations of simple interactions between the biotic/living and abiotic/nonliving parts of an ecosystem. Just as living things impact the environment in which they live, the environment impacts living things.

CONTENT STATEMENT	CONTENT ELABORATION
2.LS.2: All organisms alive today result from their ancestors, some of which may be extinct. Not all kinds of organisms that lived in the past are represented by living organisms today. Some kinds of organisms become extinct when their basic needs are no longer met or the environment changes.	**Prior Concepts Related to Interactions within Environments** **PreK-1:** Living things have physical traits, which enable them to live in different ecosystems. **Grade 2 Concepts** Fossils are preserved physical traces of past living things (e.g., shells, bones, leaves, tracks, imprints, eggs, scat). Some fossils look similar to plants and animals that are alive today, while others are very different from anything alive today. Extinction refers to the disappearance of the last individual of a kind of organism. Extinction generally occurs as a result of changed conditions where the basic needs are not met. Some kinds of living things that once lived on Earth have completely disappeared (e.g., saber-tooth cat, trilobite, mastodon). Plants and animals alive today resemble organisms that once lived on Earth (e.g., ferns, sharks). **Future Application of Concepts** **Grade 3-5:** Fossils are addressed in more detail. **Grades 6-8:** This concept is expanded to provide a partial explanation of biodiversity.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Fossils			
Test the durability of fossils made in the demonstrating science knowledge section. Compare the fossils for strength, ease of breakage and resistance to dissolving in water.	Make "fossils" of animal tracks using different kinds of soils (e.g., silt, sand, clay). Plaster of Paris can be used to make a cast or mold. Ask: Which soil worked best to make the fossil and why? Explore fossils and decide whether they came from a plant or animal. Compare the fossilized organisms to living organisms. Record similarities and differences and make inferences about relationships between the past and present.	Use a graphic organizer to compare the macroscopic features of organisms that are alive today (e.g., an elephant) with those of similar extinct organisms (e.g., a mammoth). Further examples include saber-tooth cats and house cats, mosasaurs and lizards, trilobites and insects and rugose coral and brain coral.	
Extinction			
		Research extinct animals and discuss changes to their ecosystems that may have led to their extinction.	Discuss what factors can cause a plant or animal to become extinct. Name an organism that was once abundant in the local area that now is extinct or endangered.

Grade 3

INTRODUCTION TO CONTENT STATEMENTS

GRADE BAND THEME: INTERCONNECTIONS WITHIN SYSTEMS

This theme focuses on helping students explore the components of various systems and then investigate dynamic and sustainable relationships within systems using scientific inquiry.

STRANDS

Strand Connections: Matter is what makes up all living and nonliving substances on Earth. Matter has specific properties and exists in different states. Earth's resources are made of matter. Matter can be used by living things for materials and energy. There are many different forms of energy. Each living component of an ecosystem is composed of matter and uses energy.

EARTH AND SPACE SCIENCE (ESS)	PHYSICAL SCIENCE (PS)	LIFE SCIENCE (LS)
Topic: Earth's Resources This topic focuses on Earth's resources. While resources can be living and nonliving, within this strand, the emphasis is on Earth's nonliving resources, such as water, air, rock, soil and the energy resources they represent.	**Topic: Matter and Forms of Energy** This topic focuses on the relationship between matter and energy. Matter has specific properties and is found in all substances on Earth. Heat is a familiar form of energy that can change the states of matter.	**Topic: Behavior, Growth and Changes** This topic explores life cycles of organisms and the relationship between the natural environment and an organism's (physical and behavioral) traits, which affect its ability to survive and reproduce.
CONDENSED CONTENT STATEMENTS		
3.ESS.1: Earth's nonliving resources have specific properties. **3.ESS.2:** Earth's resources can be used for energy. **3.ESS.3:** Some of Earth's resources are limited.	**3.PS.1:** All objects and substances in the natural world are composed of matter. **3.PS.2:** Matter exists in different states, each of which has different properties. **3.PS.3:** Heat, electrical energy, light, sound and magnetic energy are forms of energy.	**3.LS.1:** Offspring resemble their parents and each other. **3.LS.2:** Individuals of the same kind of organism differ in their inherited traits. These differences give some individuals an advantage in surviving and/or reproducing. **3.LS.3:** Plants and animals have life cycles that are part of their adaptations for survival in their natural environments.

NATURE OF SCIENCE GRADES 3-5

Nature of Science One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.	
Categories	**3-5**
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Observe and ask questions about the world that can be answered through scientific investigations. • Design and conduct scientific investigations using appropriate safety techniques. • Use appropriate mathematics, tools, and techniques to gather data and information. • Develop and communicate descriptions, models, explanations and predictions. • Think critically and ask questions about the observations and explanations of others. • Communicate scientific procedures and explanations. • Apply knowledge of science content to real-world challenges.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	• Science is both a body of knowledge and processes to discover new knowledge. • Science is a way of knowing about the world around us based on evidence from experimentation and observations. • Science assumes that objects and events occur in consistent patterns that are understandable through measurement and observation.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• People from many generations and nations contribute to science knowledge. • People of all cultures, genders, and backgrounds can pursue a career in science. • Scientists often work in teams. • Science affects everyday life. • Science requires creativity and imagination.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• Science develops theories based on a body of scientific evidence. • Science explanations can change based on new scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Complete *Nature of Science* document is found on pages 8-12.

Grade 3 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Earth's Resources
This topic focuses on Earth's resources. While resources can be living and nonliving, within this strand, the emphasis is on Earth's nonliving resources, such as water, air, rock, soil and the energy resources they represent.

CONTENT STATEMENT	CONTENT ELABORATION
3.ESS.1: Earth's nonliving resources have specific properties. Soil is composed of pieces of rock, organic material, water and air and has characteristics that can be measured and observed. Use the term "soil", not "dirt". Dirt and soils are not synonymous. Rocks have specific characteristics that allow them to be sorted and compared. Rocks form in different ways. Air and water are also nonliving resources. **Note:** *Rock classification is not the focus for this grade level; this is found in grade 6. At this grade, the observable characteristics of rocks can be used to sort or compare, rather than formal classification.*	**Prior Concepts Related to Properties of Nonliving Resources** **PreK-2:** Objects and materials can be sorted and described by their properties. Living things are different than nonliving things. Properties of objects and materials can change. Water and air have specific properties that can be observed and measured. **Grade 3 Concepts** The properties of air and water are introduced in the early elementary grades, so the focus at the third-grade level is on soil and rocks. Air and water are present within rocks and soil. Air and water also play an important role in the formation of rocks and soil. All are considered nonliving resources. The characteristics of rocks and soil are studied through sampling, observation and testing. This testing includes the ability of water to pass through samples of rock or soil and the determination of color, texture, composition and moisture level of soil. Measurable and observable characteristics of rocks include size and shape of the particles or grains (if present) within the rock, as well as, texture and color or the rock. Age-appropriate tools are used to test and measure the properties. The characteristics of the rock can help determine the environment in which it formed. Technology can be used to analyze and compare test results, connect to other classrooms to compare data or share samples and document the findings. **Future Application of Concepts** **Grades 4-5:** The characteristics of both soil and rock are related to the weathering and erosion of soil and rock, which result in changes on Earth's surface. The general characteristics of Earth are studied. **Grades 6-8:** Further exploration of soil and rock classification is found with the expansion of instruction to minerals and mineral properties.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Rocks			
Design a rock garden.[1]	Investigate which rocks would be best to use for building a rock garden.	Choose a famous rock feature (e.g., Grand Canyon, Uluru, Giant's Causeway) and research information on the rock type, special features and formation history. Determine what rock types would be best for creating statues, monuments or carvings like Mount Rushmore.	Identify rock, soil, air and water as examples of non-living resources. Explain that rocks form in different ways and that air and water play an important role in the formation of rocks. Organize different types of rocks[2] by characteristics such as grain size, texture, layering, color or patterns. Graphically represent and clarify the sorted results.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		Comparing soils	
Design and create a school garden by testing the soil in an area and determining what plants will grow best in the area.	Design an investigation to compare two soil samples to determine differences in their color, texture, capacity to retain water and air and ability to support plant growth.		Correlate characteristics of soil (e.g., grain size) to soil drainage and the ability to support plant life. Match soil types with appropriate applications (e.g., building structures, supporting plant life, solving erosion issues). Recognize that soil can have different texture, composition or color depending on the environment in which it formed.
		School yard soil solutions	
Identify an issue around the school yard involving poor water drainage. Based on previous investigations for soil types, determine possible solutions for the pooling water. Evaluate solutions to determine the most appropriate. Design a sustainable landscape[3] or wildlife garden for people and wildlife to enjoy.	Investigate a variety of soil types to determine drainage rates. Plan and build a simple sediment tube that can demonstrate how sand, silt, clay and organic material settle in water. Based on the findings, ask: Which soil type would create muddy water in a stream? Which soil type would wash away fastest/farthest? What properties of soil contribute to these observations?	Write a letter to the school board explaining a drainage problem in the school yard and describing how the proposed solution will address the issue.	Show that some soil types are able to absorb water while other soil types allow water to pass through.

[1]Rock Garden
[2]Types of Rocks
[3]Sustainable Landscapes

Grade 3 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Earth's Resources
This topic focuses on Earth's resources. While resources can be living and nonliving, within this strand, the emphasis is on Earth's nonliving resources, such as water, air, rock, soil and the energy resources they represent.

CONTENT STATEMENT

3.ESS.2: Earth's resources can be used for energy.

Renewable energy resources, such as wind, water or solar energy, can be replenished within a short amount of time by natural processes.

Nonrenewable energy is a finite resource, such as natural gas, coal or oil, which cannot be replenished in a short amount of time.

CONTENT ELABORATION

Prior Concepts Related to Energy from Earth's Resources
PreK-2: Wind is air in motion. Water and wind have measurable properties. Sunlight warms the air and water.

Grade 3 Concepts
Distinguishing between renewable and nonrenewable resources through observation and investigation is the emphasis for this content statement. This can be connected to learning about the different forms of energy (PS grade 3). Electrical circuits or solar panel models can be used to demonstrate different forms of energy and the source of the energy. The conservation of energy is explored within the content statement. Some of Earth's resources are limited.

Specific energy sources in Ohio are introduced, such as fossil fuels found in Ohio, new energy technologies and the development of renewable energy sources within Ohio. Ohio can be compared to other states regarding energy sources.

Future Application of Concepts
Grades 4-5: Energy is explored through electrical energy, magnetic energy, thermal energy, light and sound.

Grades 6-8: The formation of coal, oil and gas, kinetic and potential energy, thermal energy, energy conservation, energy transfer (includes renewable energy systems) and additional examination of nonrenewable resources are studied.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Renewable and nonrenewable energy			
Research, design and/or construct a model of a simple energy collection system for a specific location (use locations in Ohio or areas near water/ prairies/rivers/mountains). Provide a selection of everyday materials for the model (rather than a preplanned kit), such as PVC piping and Mylar to make a windmill or water wheel to allow student-led investigation and design. Recommend a type of energy for a new community[1] for Ohio. Design a device that utilizes renewable energy (e.g., solar oven, wind turbine, dam) and explain how energy is being transferred and used.	Develop a plan to determine the most effective method of collecting renewable energy (e.g., shapes/number/materials used in wind or water turbines, locations that allow solar panels to collect the most energy from the sun).	Research how different forms of clean energy work and explain the process using words or pictures. Use data[1] about consumption, emissions, and usage to compare different types of renewable and nonrenewable energy. Create a media presentation showing the differences between renewable and nonrenewable resources. Provide examples of each.	Sort energy types (e.g., cards with words or pictures) based on whether the energy source is renewable or nonrenewable. Explain commonalities and differences in energy types. Recognize the difference between renewable and nonrenewable energy. Be able to provide examples of each.
Local energy			
Propose a plan that addresses an issue that affects school's energy use or home energy use (e.g., expense, high emissions, power outages, switching to clean energy).	Investigate incandescent and fluorescent bulbs for light and heat emissions[2]. Compare results.	Research the source of energy for school or home. Write a persuasive essay (e.g., to a parent, principal, superintendent) about what energy type is being used and suggestions for more efficient use.	Identify whether the source(s) of local energy are renewable or nonrenewable.

[1]Energy for a New Community
[2]Incandescent and Fluorescent Bulbs

Grade 3 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Earth's Resources
This topic focuses on Earth's resources. While resources can be living and nonliving, within this strand, the emphasis is on Earth's nonliving resources, such as water, air, rock, soil and the energy resources they represent.

CONTENT STATEMENT	CONTENT ELABORATION
3.ESS.3: Some of Earth's resources are limited. Some of Earth's resources become limited due to overuse and/or contamination. Reducing resource use, decreasing waste and/or pollution, recycling and reusing can help conserve these resources.	**Prior Concepts Related to Limit of Earth's Resources** **PreK-2:** Properties of objects and materials can change. The amount of exposure to sunlight affects the warming of air, water and land. Living things acquire resources from nonliving components. Resources are necessary for living things. **Grade 3 Concepts** Within third grade, the focus is on the different types of Earth's resources, how they are used and how they can be conserved. Scientific data should be used to evaluate and compare different methods of conservation (e.g., effectiveness of different kinds of recycling such as paper vs. metal). The concentration is the science behind the conservation of resources and why certain resources are limited. Reducing or limiting the use and/or waste of resources should be emphasized (rather than concentrating only on recycling of resources). **Future Application of Concepts** **Grades 4-5:** Conservation of matter, environmental changes through Earth's history and erosion (loss of resources/contamination) are studied. **Grades 6-8:** Common and practical uses of soil, rock and minerals (geologic resources), biogeochemical cycles, global climate patterns and interactions between the spheres of Earth (Earth Systems) are explored.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Water conservation			
Design and propose a plan to conserve water or reduce water pollution. If possible, use a water issue specific to your area. Investigate a way that pollution is affecting the environment (e.g., impact of an oil spill on animals, fertilizer pollution in ponds, groundwater pollution). Provide possible solutions to reduce the negative impacts.		Research the ways water gets polluted and report findings. Depending upon your school's watershed, investigate types of pollution impacting the Ohio River or Lake Erie. Create a persuasive essay discussing pollution impacting the local watershed and ideas about ways to reduce the pollution. Create commercials about ways to conserve water in your everyday life.	
Reuse and repurpose			
Conduct a repurpose challenge by designing new uses for trash or throw away items. Redesign a consumer product (e.g., ice cream container, snack bag) so that it results in less material being thrown away.	Create a model landfill (e.g., plastic box with dirt, water and various organic and inorganic consumer products). Observe it over the course of the year, recording changes to the various materials. Identify the types of materials which biodegrade and those that do not.	Research how long it takes common waste materials to biodegrade. Report findings and describe the possible impacts of various materials on the environment 5, 10 or 50 years in the future.	Identify the materials found in common items (e.g., aluminum cans, paper, pencils, plastic water bottles).

Grade 3 continued

PHYSICAL SCIENCE (PS)

Topic: Matter and Forms of Energy
This topic focuses on the relationship between matter and energy. Matter has specific properties and is found in all substances on Earth. Heat is a familiar form of energy that can change the states of matter.

CONTENT STATEMENT	CONTENT ELABORATION
3.PS.1: All objects and substances in the natural world are composed of matter. Matter takes up space and has mass. Differentiating between mass and weight is not necessary at this grade level.	**Prior Concepts Related to Matter** **PreK-2:** Objects are things that can be seen or felt. Properties of objects may be described, measured and sorted. The physical properties of water change as observed in weather. Air has mass and takes up space. **Grade 3 Concepts** Objects are composed of matter and matter has observable properties. Matter is anything that has mass and takes up space. All solids, liquids and gases are made of matter. The atomic and subatomic nature of matter is not appropriate at this grade level. Mass is defined as a measure of how much matter is in an object. The more matter there is in an object, the greater the mass. Volume is a measure of the amount of space an object occupies. Provide opportunities to investigate and experiment with different methods of measuring mass and liquid volume using the metric system and nontraditional units (e.g., nails, paper clips). Objects are made of smaller parts, some too small to be seen even with magnification. Matter continues to exist, even when broken into pieces too tiny to be visible. **Future Application of Concepts** **Grades 4-5:** The mass and total amount of matter remains the same when it undergoes a change, including phase changes. The sum of the mass of the parts of an object is equal to the weight (mass) of the entire object. **Grades 6-8:** The atomic model is introduced. Properties are explained by the arrangement of particles.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Properties of matter			
Design a method or device to keep a chocolate bar from melting in a hot car.		Design a simple demonstration that will show that air is made of matter. Given three different items, measure as many properties for each item as possible. Record the measurements for each item on a separate index card. Switch samples with another group and identify which set of measurements belong with which item.	Explain that water continues to exist after it evaporates.
Mass and volume			
Design a backpack with appropriate pockets/sections that has the largest volume but the least mass. Mass and volume measurements can be in nonstandard units.	Make observations of a material that absorbs water (e.g., water beads, magic grow animals, diapers). Measure the mass of the materials and volume of water absorbed over time. Graph and identify patterns in their growth rate.	Measure and compare the masses of two different materials that have the same volume (e.g., piece of foam and equal-sized piece of wood).	Measure the mass of an object using standard and nonstandard units. Measure the volume of an object using standard and nonstandard units.

Grade 3 continued

PHYSICAL SCIENCE (PS)

Topic: Matter and Forms of Energy
This topic focuses on the relationship between matter and energy. Matter has specific properties and is found in all substances on Earth. Heat is a familiar form of energy that can change the states of matter.

CONTENT STATEMENT	CONTENT ELABORATION
3.PS.2: Matter exists in different states, each of which has different properties. The most recognizable states of matter are solids, liquids and gases. Shape and compressibility are properties that can distinguish between the states of matter. One way to change matter from one state to another is by heating or cooling.	**Prior Concepts Related to Matter** **PreK-2:** Materials can be sorted by properties. The physical properties of water change as observed in weather. **Grade 3 Concepts** Gases, liquids and solids are different states of matter that have different properties. Liquids and solids do not compress into a smaller volume as easily as do gases. Liquids and gases flow easily, but solids do not flow easily. Solids retain their shape and volume (unless a force is applied). Liquids assume the shape of the part of the container that they occupy (retaining their volume). Gases assume the shape and volume of their containers. Only solids, liquids and gases are appropriate at this grade level, even though other phases have been identified. Heating may cause a solid to melt to form a liquid or cause a liquid to boil or evaporate to form a gas. The differences between boiling and evaporation are not appropriate at this grade level. Cooling may change a gas into a liquid or cause a liquid to freeze and form a solid. Conducting experiments or investigations that demonstrate phase changes, such as the melting or freezing of substances other than water (e.g., vinegar, vegetable oil, sugar, butter), can be used to reinforce the concept that materials other than water also go through phase changes. **Future Application of Concepts** **Grades 4-5:** The amount of mass and matter remains the same during phase changes. **Grades 6-8:** Atomic theory is introduced. Properties of solids, liquids and gases are related to the spacing and motion of particles. Thermal energy and temperature are related to the motion of particles.

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
States of matter			
	Investigate frozen water balloons and the various conditions that affect the rate at which the ice melts. Determine which material (e.g., sand, salt, calcium chloride) melts ice the fastest. Design and conduct an investigation to determine which liquid/substance will freeze fastest. Make predictions, then graph and present conclusions.	Melt a variety of substances (e.g., candle, chocolate bar, butter, bacon grease) and compare the temperatures at which they melt.	Categorize a variety of materials at room temperature as solids, liquids or gases. Construct a snowman and observe over time. Identify the phase changes of water that occur.

Grade 3 continued

PHYSICAL SCIENCE (PS)

Topic: Matter and Forms of Energy
This topic focuses on the relationship between matter and energy. Matter has specific properties and is found in all substances on Earth. Heat is a familiar form of energy that can change the states of matter.

CONTENT STATEMENT

3.PS.3: Heat, electrical energy, light, sound and magnetic energy are forms of energy.

There are many different forms of energy. Energy is the ability to cause motion or create change. The different forms of energy that are outlined at this grade level should be limited to familiar forms that a student is able to observe.

CONTENT ELABORATION

Prior Concepts Related to Sound, Energy and Motion
PreK-2: Vibrations are associated with sound. An object is in motion when its position is changing. Forces change the motion of an object. Sunlight is the principal source of energy on Earth and warms Earth's land, air and water. Weather changes occur due to changes in energy. Living things require energy. Plants get energy from sunlight.

Grade 3 Concepts
Examples of energy causing motion or creating change include a falling rock causing a crater to form on the ground, heating water causing liquid water to change into a gas, light energy from the sun contributing to plant growth, electricity causing the blades of a fan to move, electrically charged objects causing movement in uncharged objects or other electrically charged objects, sound from a drum causing rice sitting on the drum to vibrate and magnets causing other magnets and some metal objects to move.

Investigations (3-D or virtual) are used to demonstrate the relationship between different forms of energy and motion. It is not appropriate at this grade level to explore the different types of energy in depth or use wave terminology when discussing energy. These will be developed at later grades. There often is confusion between the concepts of force and energy. Force can be thought of as a push or pull between two objects and energy as the property of an object that can cause change. If forces actually push or pull something over a distance, then there is an exchange of energy between the objects. The differences between force and energy will be developed over time and are not appropriate for this grade level. The word "heat" is used loosely in everyday language, yet it has a very specific scientific meaning. Usually what is called heat is actually thermal or radiant energy. An object has thermal energy due to the random movement of the particles that make up the object. Radiant energy is that which is given off by objects through space (e.g., warmth from a fire, solar energy from the sun). "Heating" is used to describe the transfer of thermal or radiant energy to another object or place. Differentiating between these concepts is not appropriate at this grade. This document uses the same conventions as noted in the NAEP 2009 Science Framework (see page 29) where "heat" is used in lower grades. However, the word "heat" has been used with care so it refers to a transfer of thermal or radiant energy.

Future Application of Concepts

Grades 4-5: Processes of energy transfer and transformation are introduced. Heat, electrical energy, light and sound are explored in more detail.

Grades 6-8: Energy is classified as kinetic or potential. The concepts of conservation of energy and thermal energy as it relates to particle motion are introduced.

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		Energy	
Design a more effective box for pizza that will keep it warm and be eco-friendly. Design, construct and test a small boat or aircraft that can move in different directions or against the flow of water/air. Document the forms of energy involved and the resulting motion.	Explore ways that a pot of warm water can cause change (e.g., warm water can cause butter to melt, pouring water on a sand structure can cause the structure to change shape).	Compare the motion of a drop of food coloring in various temperatures of water. Explain ways a magnet can cause motion or create change. Examples of possible answers include: a magnet can cause other magnets and some metallic items to move toward it, a magnet can cause other magnets to move away from it.	Recognize that energy can cause motion or create change. Identify objects with energy in the environment (e.g., moving water, windmill, water wheel, sunlight) and determine what types of energy they have.

Grade 3 continued

LIFE SCIENCE (LS)

Topic: Behavior, Growth and Changes
This topic explores life cycles of organisms and the relationship between the natural environment and an organism's (physical and behavioral) traits, which affect its ability to survive and reproduce.

CONTENT STATEMENT	CONTENT ELABORATION
3.LS.1: Offspring resemble their parents and each other. Individual organisms inherit many traits from their parents indicating a reliable way to transfer information from one generation to the next. Some behavioral traits are learned through interactions with the environment and are not inherited.	**Prior Concepts Related to Behavior, Growth and Changes** **PreK-2:** Similarities and differences exist among individuals of the same kind of plant or animal. **Grade 3 Concepts** Organisms are similar to their parents in appearance and behavior but still show some variation. Although the immature stages of some living things may not resemble the parents, once the offspring matures, it will resemble the parent. At this grade level, the focus is on establishing, through observation, that organisms have a reliable mechanism for ensuring that offspring resemble their parents. It is not appropriate or necessary to introduce the genetic mechanisms involved in heredity; however, care should be taken to avoid introducing the misconception that the individual organism has a way to select the traits that are passed to the next generation. As part of the study of the life cycle of organisms, the physical appearance of the adults will be compared to the offspring (e.g., compare butterflies to determine if offspring look exactly like the parents). A considerable amount of animal behavior is directly related to getting materials necessary for survival (e.g., food, shelter) from the environment and this influences what an animal learns. The focus at this grade level is on examples provided through observation or stories of animals engaging in instinctual and learned behaviors. Some organisms have behavioral traits that are learned from the parent (e.g., hunting). Other behavioral traits are in response to environmental stimuli (e.g., a plant stem bending toward the light). At this grade level, the definition of either instinctual or learned behavior is not necessary. The focus is on making observations of different types of plant and animal behavior. Technology (e.g., a webcam) can be used to observe animals in their natural or human-made environments. **Note:** *Human genetic study is not recommended since not all students may have information available from their biological parents.* **Future Application of Concepts** **Grades 6-8:** These observations will build to a description and understanding of the biological mechanisms involved in ensuring that offspring resemble their parents. Cell Theory will be introduced which will explore how cells come from pre-existing cells and how new cells get the genetic information of the old cells. The genetic details of reproduction will be outlined.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Offspring resemble their parents			
	Make comparisons between a plant and its offspring. Harvest the seeds from a plant (e.g., fast growing plant, bean) or use cuttings. Grow the seeds or cuttings and compare the offspring to the original plant (e.g., actual plant, photos, preserved specimens). Conduct a real-time observational study of a familial grouping of organisms. Use webcams to view animals in their natural or simulated habitat to observe and record physical characteristics of the animals. Falcon cams are used by the Ohio Department of Natural Resources and can be used for this study.	Based on data from observational studies of offspring and their parents, develop a chart that compares features (e.g., stages of development, food sources, where they are found in the habitat, physical appearance) to emphasize the similarities and differences. Make a chart to identify physical traits that differ among humans and those that are the same for all.	Use pictures of animal parents and babies to demonstrate similarities and differences. Match animal babies to their parents. Using pictures of many different people, from different periods and places in the world throughout human history, identify features all humans have that stay the same from generation to generation. Explain that all humans have hearts, skin, stomachs, lungs, bones, eyes and other organs.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Wildlife watching			
Redesign the schoolyard to make it better for wildlife. Make wildlife observations around the school yard. Identify how observed behaviors are related to survival (e.g., food, water, shelter). Identify ways to attract more wildlife to the school yard.	Conduct a real-time observational study of plants and animals around the school, a park, or a nature center over the course of a season or year. Make observations of which plants and animals are present and wildlife behaviors. Compare one habitat to another (e.g., the school yard to the park) for similarities and differences in plant and animal life and behavior.	Create graphs or charts to share data collected from a wildlife observational study. Identify patterns in the data and show how observed behaviors (plant and animal) help the organisms survive.	Observe a group of the same type of wildlife (e.g., apples, dandelions, worms, squirrels, cardinals, blue jays) to identify variation within the species (e.g., different sizes, coloring).
Animals			
Identify ways that humans can assist animals by providing resources that are lacking in the environment due to human impacts or natural environmental changes (e.g., building bat houses, bird feeders). Choose an example to design and construct. Monitor its use.		Investigate various types of learned and inherited behaviors in an animal and create a pamphlet describing the behaviors. Investigate how human activity is changing animals' behaviors (e.g., animals being fed, leaving trash outside in cans) and summarize findings. Make real-time observations of animals (e.g., in the schoolyard, webcams, trail cameras, videos) and identify which behaviors are instinctive, which are learned, and which are a response to the environment. Include evidence to support the identification.	Identify structures that are built by animals (e.g., nests, dams) and the purpose they serve for the animal.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	Plants		
	Plant multiple seeds in a clear container, each oriented in a different direction. Observe the direction of root and stem growth. Test additional types of seeds to see if there is a general behavior pattern for plants.	Based on plant behavior investigations write a short report using the data collected to explain observations.	Give examples of variations among individuals of a local population of dandelions (e.g., height, color, weight). Match plant behaviors with their causes (e.g., bending toward the light, shedding leaves, wilting).

Grade 3 continued

LIFE SCIENCE (LS)

Topic: Behavior, Growth and Changes
This topic explores life cycles of organisms and the relationship between the natural environment and an organism's (physical and behavioral) traits, which affect its ability to survive and reproduce.

CONTENT STATEMENT	CONTENT ELABORATION
3.LS.2: Individuals of the same kind of organism differ in their inherited traits. These differences give some individuals an advantage in surviving and/or reproducing. Plants and animals have physical features that are associated with the environments where they live. Plants and animals have certain physical or behavioral characteristics that influence their chances of surviving in particular environments. **Note:** *The focus is on the individual, not the population. Adaptation is not the focus at this grade level.*	**Prior Concepts Related to Behavior, Growth and Changes** **PreK-2:** Similarities and differences exist among individuals of the same kinds of plants and animals. Living things have physical traits and behaviors that influence their survival. **Grade 3 Concepts** Organisms have different structures and behaviors that serve different functions. Some plants have leaves, stems and roots; each part serves a different function for the plant. Some animals have wings, feathers and beaks; each part serves a different function for the animals. The observation of body parts should be limited to gross morphology and not microscopic or chemical features. Comparison across species is not appropriate at this grade level; only observation of variation within the same species is expected. This content statement can be combined with the observation of the life cycles of organisms and/or the observation of the similarity between offspring and parents. There may be variations in the traits that are passed down that increase the ability of organisms to survive and reproduce. Some variations in traits that are passed down may reduce the ability of organisms to survive and reproduce. Some variations in traits that are passed down may have no appreciable effect on the ability of organisms to survive and reproduce. Variations in physical features among animals and plants can help them survive in different environmental conditions. Variations in color, size, weight, etc., can be observed as the organism develops. Plants and animals that survive and reproduce pass their features (traits) on to their offspring and future generations. Some grade-appropriate organisms to study are plants (e.g., radishes, beans) and animals (e.g., butterflies, moths, beetles, brine shrimp). Comparisons can be made in nature or virtually. Tables and diagrams (e.g., Venn) can be used to illustrate the similarities and differences between individuals of the same type. **Future Application of Concepts** **Grades 4-5:** Changes in the environment may benefit some organisms and be a detriment to other organisms. **Grades 6-8:** The reproduction of organisms will explain how traits are transferred from one generation to the next.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Plant investigation			
Make observations in a community garden or school yard and identify growing conditions that may be lacking (e.g., access to water, soil, sunlight). Develop a solution to the problem (e.g., irrigation system, raised beds, planting additional plants). A soil and water district representative or agricultural extension agent can assist in this process.	Conduct a comparative study of a population of plants in the school yard. Measure and compare some of the following: root size (width and depth), leaf size (length and width), flower color, number of petals, time of year when plant blooms, number of seeds produced or when seeds are produced. Investigate the variations of each plant feature studied.	Using data from the comparative plant study organize results to see differences in the physical features of the same type plants.	Identify similarities and differences between various native plants.
Plants			
Investigate a variety of greenhouse and terrarium designs. Decide what type of structure would be the right fit for your classroom or schoolyard and design a model.		Investigate the movement of colored water in celery to demonstrate the function of the stem and interpret how the food coloring travels to the leafy celery top. Have some celery stalks "stalks down" and others "leaves down" to investigate whether the food coloring moves in both directions. It is not important to know the term "xylem", but rather to understand that water is absorbed through the roots and transported through the stems to provide water to the rest of the plant.	Identify some plants from different environments for comparisons (e.g. cacti, pine trees, deciduous trees, prairie grass, swamp wildflowers, forest wildflowers). Explore why some plants may not be found in the school yard (e.g., cacti, swamp-loving plants) to understand the relationship between habitat and plant type.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Animals			
In the process of planning an investigation to study the life cycle of a butterfly, evaluate the design of three emergence cages.[1] Evaluate each cage using scientific knowledge about the needs of butterflies. Using the information from the study, design and build an "improved" butterfly emergence cage.	Investigate the pill bug and the bug's behaviors (e.g., light/dark, wet/dry, soil/sand) and compare resulting behavior with their natural habitat.	Research how the traits of polar bears allow them to survive in the Arctic habitat. Identify how these traits are impacting the polar bears in a changing habitat. Describe how inherited human traits can help in survival (e.g., how the shape of teeth helps in the consumption of food, why walking upright is beneficial). Research inherited human traits that can vary. Predict whether these traits provide a survival advantage, disadvantage or have no effect.	Provide a habitat and identify an animal that would thrive in that habitat.

Grade 3 continued

LIFE SCIENCE (LS)

Topic: Behavior, Growth and Changes
This topic explores life cycles of organisms and the relationship between the natural environment and an organism's (physical and behavioral) traits, which affect its ability to survive and reproduce.

CONTENT STATEMENT	CONTENT ELABORATION
3.LS.3: Plants and animals have life cycles that are part of their adaptations for survival in their natural environments. Worldwide, organisms are growing, reproducing, dying and decaying. The details of the life cycle are different for different organisms, which affects their ability to survive and reproduce in their natural environments. **Note:** *The names of the stages within the life cycles are not the focus.*	**Prior Concepts Related to Behavior, Growth and Changes** **PreK-2:** Plants and animals have variations in their physical traits that enable them to survive in a particular ecosystem. Some organisms exhibit seasonal behaviors that enable them to survive environmental conditions and changes. **Grade 3 Concepts** Plants and animals have life cycles that are adapted to survive in distinct ecosystems (e.g., trees lose their leaves in the winter to conserve water). Most life cycles start with birth, budding or germination, then progress to growth, development, adulthood, reproduction and death. The process can be interrupted at any stage. The details of the life cycle are different for different organisms. Observation of the complete life cycle of an organism can be made in the classroom (e.g., butterflies, mealworms, plants) or virtually. Hand lenses, magnifying lenses, metric rulers and scales are some of the tools that can be used to question, explore and investigate the physical appearance of living things. When studying living things, ethical treatment of animals and safety must be employed. Respect for and proper treatment of living things must be modeled. For example, shaking a container, rapping on insect bottles, unclean cages or aquariums, leaving living things in the hot sun or exposure to extreme temperatures (hot or cold) must be avoided. The National Science Teachers Association (NSTA) has a position paper to provide guidance in the ethical use and treatment of animals in the classroom for review. **Future Application of Concepts** **Grades 4-5:** Organisms perform a variety of roles in an ecosystem. **Grades 6-8:** The structure and organization of organisms and the necessity of reproduction for the continuation of the species will be detailed.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Animal life cycles			
Use knowledge about a species' lifecycle and needs to design an enclosure for that species.	Plan an investigation to study the lifecycle of a species (e.g., butterfly, moth, darkling beetle, brine shrimp, worm, mealworm, chicken). Make observations and think about animal needs at different stages of the life cycle. Note changes in physical appearance and body parts.	Compare the life cycles of two species. Identify differences and share findings in a presentation. Compare different stages of the human life cycle (e.g., infant, toddler, child, adolescent, young adult, older adult). Identify physical and behavioral features.	Given photographs of stages of a variety of animal life cycles, place them in sequence from egg or infant to adult.
Plant life cycles			
	Design an investigation to find out the optimal conditions for seed germination.	Compare the life cycles of different plants noting similarities and differences. Include the time each stage takes, what it looks like and where each plant might be found.	Choose a plant and create a life cycle diagram for that plant.

Grade 4

INTRODUCTION TO CONTENT STATEMENTS

GRADE BAND THEME: INTERCONNECTIONS WITHIN SYSTEMS

This theme focuses on helping students explore the components of various systems and then investigate dynamic and sustainable relationships within systems using scientific inquiry.

STRANDS

Strand Connections: Heat and electrical energy are forms of energy that can be transferred from one location to another. Matter has properties that allow the transfer of heat and electrical energy. Heating and cooling affect the weathering of Earth's surface and Earth's past environments. The processes that shape Earth's surface and the fossil evidence found can help decode Earth's history.

EARTH AND SPACE SCIENCE (ESS)	PHYSICAL SCIENCE (PS)	LIFE SCIENCE (LS)
Topic: Earth's Surface This topic focuses on the variety of processes that shape and reshape Earth's surface.	**Topic: Electricity, Heat and Matter** This topic focuses on the conservation of matter and the processes of energy transfer and transformation, especially as they relate to heat and electrical energy	**Topic: Earth's Living History** This topic focuses on using fossil evidence and living organisms to observe that suitable habitats depend upon a combination of biotic and abiotic factors.
CONDENSED CONTENT STATEMENTS		
4.ESS.1: Earth's surface has specific characteristics and landforms that can be identified. **4.ESS.2:** The surface of Earth changes due to weathering. **4.ESS.3:** The surface of Earth changes due to erosion and deposition.	**4.PS.1:** When objects break into smaller pieces, dissolve, or change state, the total amount of matter is conserved. **4.PS.2:** Energy can be transferred from one location to another or can be transformed from one form to another.	**4.LS.1:** Changes in an organism's environment are sometimes beneficial to its survival and sometimes harmful. **4.LS.2:** Fossils can be compared to one another and to present-day organisms according to their similarities and differences.

NATURE OF SCIENCE GRADES 3-5

Nature of Science One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.	
Categories	**3-5**
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Observe and ask questions about the world that can be answered through scientific investigations. • Design and conduct scientific investigations using appropriate safety techniques. • Use appropriate mathematics, tools, and techniques to gather data and information. • Develop and communicate descriptions, models, explanations, and predictions. • Think critically and ask questions about the observations and explanations of others. • Communicate scientific procedures and explanations. • Apply knowledge of science content to real-world challenges.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	• Science is both a body of knowledge and processes to discover new knowledge. • Science is a way of knowing about the world around us based on evidence from experimentation and observations. • Science assumes that objects and events occur in consistent patterns that are understandable through measurement and observation.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• People from many generations and nations contribute to science knowledge. • People of all cultures, genders, and backgrounds can pursue a career in science. • Scientists often work in teams. • Science affects everyday life. • Science requires creativity and imagination.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• Science develops theories based on a body of scientific evidence. • Science explanations can change based on new scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Complete *Nature of Science* document is found on pages 8-12.

Grade 4 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Earth's Surface
This topic focuses on the variety of processes that shape and reshape Earth's surface.

CONTENT STATEMENT	CONTENT ELABORATION
4.ESS.1: Earth's surface has specific characteristics and landforms that can be identified. About 70 percent of the Earth's surface is covered with water and most of that is the ocean. Only a small portion of the Earth's water is freshwater, which is found in rivers, lakes, groundwater and glaciers. Earth's surface can change due to erosion and deposition of soil, rock or sediment. Catastrophic events such as flooding, volcanoes and earthquakes can create landforms.	**Prior Concepts Related to Surface of Earth** **PreK-2:** Wind and precipitation can be measured. Water can change state. Heating and cooling can change the properties of materials. Living things can cause changes on Earth. **Grade 3:** The composition and characteristics of rocks and soil are studied. **Grade 4 Concepts** Earth is known as the Blue Planet because about 70 percent of Earth's surface is covered in water. Freshwater is a small percentage of the overall water found on Earth; the majority is oceanic. There are many different processes that continually build up or tear down the surface of Earth. These processes include erosion, deposition, volcanic activity, earthquakes, glacial movement and weathering. Beginning to recognize common landforms or features through field investigations, field trips, topographic maps, remote sensing data, aerial photographs, physical geography maps and/or photographs are important ways to understand the formation of landforms and features. Common landforms and features include streams, deltas, floodplains, hills, mountains/mountain ranges, valleys, sinkholes, caves, canyons, glacial features, dunes, springs, volcanoes and islands. Connecting the processes that occur to the resulting landform, feature or characteristic is emphasized. This can be demonstrated through experiments, investigations (including virtual experiences) or field observations. Technology can help illustrate specific features that are not found locally or demonstrate change that occurred (e.g., using satellite photos of an erosion event such as flooding). **Future Application of Concepts** **Grade 5:** Earth is a planet in the solar system that has a unique composition. **Grades 6-8:** Global seasonal changes are introduced, including monsoons and rainy seasons, which can change erosion and deposition patterns. Changes in the surface of Earth are examined using data from the rock record and through the understanding of plate tectonics and the interior of Earth. Historical studies of erosion and deposition patterns are introduced, in addition to soil conservation, the interaction of Earth's spheres and erosion and deposition related to oceans.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Water on Earth exploration			
	Investigate the amount and types (e.g., saltwater, frozen water, freshwater) of water that cover Earth's surface. Create a grid on actual maps of Earth, or regions of Earth, to determine the portion that is covered in water. Determine the amount of fresh and salt water.	Create a visual representation of where water exists on Earth (e.g., oceans, streams and rivers, glaciers and ice caps, groundwater, lakes, atmosphere, plants and animals). Create a model (e.g., virtual, graphic, or 3-D) of a type of body of water including the landforms that surround it.	Explain why Earth is known as the Blue Planet.
Erosion and deposition			
	Use a model of a landform to investigate erosion. Create a 3-D model of a landform in a waterproof tub or container using natural materials such as dirt, sand and grass. Pour water over the model to investigate how water moves and settles around the landform. Design a model of glacial movement over land and use it to observe, measure and record evidence of the effects of the glacier on the land. Take time-lapse photos, if possible, of the glacier models and compare them with photos of real-life landscape changes due to the effects of glaciers.	Explain how a landscape is affected by glacial movement, how the environment would be affected by such changes, how a glacier would impact various soil types, and how rising temperatures might affect the rate of glacial movement and change.	Identify the processes that can change the surface of Earth (e.g., erosion, deposition, volcanic activity, earthquakes, glacial movement, weathering). Identify landforms or features using maps and photographs.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		Catastrophic events	
Investigate catastrophic events that have changed Earth's surface (e.g., landslides, flash flooding, volcanoes, earthquakes), design and propose a plan to reduce negative effects on humans and/or the ecosystem.		Research a specific landform of interest (e.g., Cape Cod, Mt. St. Helens, Mississippi River, Rocky Mountains, Hawaiian Islands, Grand Canyon, Mississippi Delta, Hood Canal, Mendenhall Glacier). Explain how the landform was formed and has changed over the years. Include any catastrophic events that may have changed it, as well as any cultural or historical events that have taken place there.	
		Landforms	
Use information about landforms to plan an efficient route for a highway, location for a ski lodge, location for a state park, amusement park, etc. using a topographic map and other resources. Consider the location of landforms (e.g., mountains, hills, rivers, plains) and how the landforms impact the location and design.		Explain the similarities and differences of a variety of landforms. Discuss the ways each landform was formed. Create a relief or topographic map of a neighborhood or region. Research different landforms and map features that are in the area. Use blackline maps of the area and color in different landforms. Create a key for the map, to show the different heights and depths of landforms (e.g., hills, mountains, canyons, chasms) by using different patterns or colors.	Identify common landforms from maps or graphics (e.g., streams, deltas, floodplains, hills, mountains/mountain ranges, valleys, sinkholes, caves, canyons, glacial features, dunes, springs, volcanoes, islands).

Grade 4 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Earth's Surface
This topic focuses on the variety of processes that shape and reshape Earth's surface.

CONTENT STATEMENT	CONTENT ELABORATION
4.ESS.2: The surface of Earth changes due to weathering. Rocks change shape, size and/or form due to water or glacial movement, freeze and thaw, wind, plant growth, acid rain, pollution and catastrophic events such as earthquakes, flooding, and volcanic activity. **Note:** *Differentiating between chemical and physical weathering is not the focus at this grade level.*	**Prior Concepts Related to Weathering** **PreK-2:** Wind is air in motion. Water and wind have measurable properties. Water changes state. Properties of materials change when exposed to various conditions (e.g., heating, cooling). Living organisms interact with their environment. **Grade 3:** Rocks and soil have unique characteristics. Soil contains pieces of rock. **Grade 4 Concepts** Different types of rock weather at different rates due to specific characteristics of the rock and the exposure to weathering factors (e.g., freezing/thawing, wind, water). Weathering is defined as a group of processes that change rock at or near Earth's surface. Some weathering processes take a long time to occur, while some weathering processes occur quickly. The weathering process is observed in nature, through classroom experimentation or virtually. Seeing tree roots fracturing bedrock or the effect of years of precipitation on a marble statue can illustrate ways that rocks change shape over time. Investigations can include classroom simulations, laboratory testing and field observations. **Future Application of Concepts** **Grade 5:** Earth is a planet in the solar system that has a unique composition. **Grades 6-8:** Global seasonal changes and patterns are introduced, including temperature fluctuations/ranges, monsoons and/or rainy seasons which can impact the weathering of Earth's surface. The relationship between the characteristics of rocks and the environment in which they form is explored, as well as how rocks break down (weather) and are transported (erosion). Water flows through rock and soil at different rates. The causes of changes on Earth's surface are investigated.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	Weathering		
Using the connection between weathering and changes to the surface of the Earth, write and present a proposal for the building of a stationary object (e.g., statue, patio, staircase) utilizing materials that are resistant to weathering.	Use a weak acid (e.g., vinegar, soda, lemon juice) to investigate the effects of acid rain on various types of rocks or structures. Design an investigation of the freeze-thaw cycle and how this process breaks down rock and wood over time (e.g., a temperature-effect simulation). Relate this to the action of water, rain and snow which enters the crevices of rock, pavement, concrete or wood, freezing and expanding the materials, eventually breaking them down into smaller pieces.	Create a visual representation of the signs of weathering in a local city or town. Indicate the causes of weathering for each occurrence.	Discuss how potholes form. Recognize that water, wind, pollution/ gases in the air, ice movement, earthquakes, volcanoes, freezing/thawing and plant action can all weather rock and soil.

Grade 4 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Earth's Surface
This topic focuses on the variety of processes that shape and reshape Earth's surface.

CONTENT STATEMENT	CONTENT ELABORATION
4.ESS.3: The surface of Earth changes due to erosion and deposition. Liquid water, wind and ice physically remove and carry rock, soil and sediment (erosion) and deposit the material in a new location (deposition). Gravitational force affects movements of water, rock and soil.	**Prior Concepts Related to Erosion and Deposition** **PreK-2:** Wind is air in motion. Water and wind have measurable properties. Water changes state. Forces change the motion of an object. Some forces act without touching (e.g., gravitational forces). **Grade 3:** Soil and rock have unique characteristics. Soil and rock are nonliving resources that can be conserved. **Grade 4 Concepts** Erosion is a process that transports rock, soil or sediment to a different location. Weathering is the breakdown of large rock into smaller pieces of rock. Erosion is what carries the weathered material to a new location. Gravity plays an important role in understanding erosion, especially catastrophic events like mass movement (e.g., mudslides, avalanches, landslides) or flooding. Erosion is a "destructive" process and deposition is a "constructive" process. Erosion and deposition directly contribute to formation of the landforms and features that are included in grade 4. Topographic maps and aerial photographs can be used to locate erosional and depositional areas in Ohio. Surficial geology maps also can illustrate the patterns of glacial erosion and deposition that have occurred. Field trips and field investigations (may be virtual) are recommended as erosional and depositional features that can be seen locally or within the state can help to connect the concept of erosion and deposition to the real world. **Future Application of Concepts** **Grades 6-8:** Historical studies of erosional and depositional patterns, soil conservation, the interaction of Earth's spheres, ocean features specific to erosion and deposition, and plate tectonics are introduced. Global seasonal changes including monsoons and rainy seasons, which can change erosion and deposition patterns, are also introduced.

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Erosion			
Conduct a walking field trip around the school grounds or a local park. Investigate areas where there have been slow changes, (e.g., stream beds, steps, sidewalks, pavement). Design a solution to slow the rate of erosion (e.g., plant choices, fencing, wind barriers).	Design and conduct an experiment to compare the amount of erosion between soil with varying amounts of surface coverage (e.g., no coverage, rocks, dead leaves, growing plants). Use data to conclude how erosion is best minimized.	Use models, pictures or other visual representations to compare erosion and deposition. Cite the importance of erosion in the process of reshaping Earth's surface using specific real-world examples (e.g., Mississippi River).	Describe the different agents of erosion (e.g., wind, water, ice).
Deposition			
		Cite the importance of deposition in the process of reshaping Earth's surface using specific real-world examples (e.g., Mississippi River).	Describe the features created by deposition.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Connections among weathering, erosion, and deposition			
Simulate wind erosion and water erosion (e.g., use sand to build a mountain and then use a straw and/or watering can to erode it). Make observations and relate the erosion processes to weathering and sediment deposition. Propose ways to slow the erosion. Design a model to show the erosion and deposition occurring with wave movement in coastal environments, taking into account the beach composition and atmospheric conditions. Experiment with a variety of materials and factors (e.g., plant life, coastline composition, slope) to determine which environment is the most stable for human activity. Design and test a solution to slow the rate of erosion for coastline preservation.	Investigate different farming or landscaping methods that slow erosion. Connect the method with the topography of the area. Describe why that method is appropriate for that area.	View images where erosion and deposition have occurred (e.g., waterfalls, sand dunes, rivers, glaciers, canyons). Determine the causes of the erosion and deposition and sort them accordingly. Describe how these processes are changing Earth's surface. Observe and compare places where roots can help prevent/slow erosion and places where roots cause erosion.	Write cause and effect statements that explain changes in Earth's surface from weathering, erosion, and deposition. Identify specific instances of erosion and deposition across an extended period of time through time lapse video. Describe how weathering, erosion and deposition work together as a continual process.

Grade 4 continued

PHYSICAL SCIENCE (PS)

Topic: Electricity, Heat and Matter
This topic focuses on the conservation of matter and the processes of energy transfer and transformation, especially as they apply to heat and electrical energy.

CONTENT STATEMENT

4.PS.1: When objects break into smaller pieces, dissolve, or change state, the total amount of matter is conserved.

When an object is broken into smaller pieces, when a solid is dissolved in a liquid or when matter changes state (solid, liquid, gas), the total amount of matter remains constant.

Note: *Differentiation between mass and weight is not necessary at this grade level.*

CONTENT ELABORATION

Prior Concepts Related to Changes of Matter
PreK-2: Simple measuring instruments are used to observe and compare properties of objects. Changes in objects are investigated.

Grade 3: Objects are composed of matter, which has mass and takes up space. Matter includes solids, liquids and gases (air). Phase changes are explored. Heating and cooling is one way to change the state of matter.

Grade 4 Concepts
Some properties of objects may stay the same even when other properties change. For example, water can change from a liquid to a solid, but the mass of the water remains the same. Parts of an object or material may be assembled in different configurations but the mass remains the same. The sum of the mass of all parts in an object equals the mass of the object.

When a solid is dissolved in a liquid, the mass of the mixture is equal to the sum of the masses of the liquid and solid.

At this grade level, the discussion of conservation of matter should be limited to a macroscopic, observable level. Conservation of matter should be developed from experimental evidence collected in the classroom. After the concept has been well established with experimental data and evidence using closed systems (i.e., systems where matter cannot enter or leave the system), investigations can include interactions that are more complex where the mass may not appear to stay constant (e.g., fizzing tablets in water). Mass is an additive property of objects and volume is usually an additive property for the same material at the same conditions. However, volume is not always an additive property, especially if different substances are involved. For example, mixing alcohol with water results in a volume that is significantly less than the sum of the volumes.

Future Application of Concepts
Grades 6-8: Conservation of matter in phase changes and chemical reactions is explained by the number and type of atoms remaining constant. The idea of conservation of energy is introduced.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	**Demonstrating science knowledge**	**Interpreting and communicating science concepts**	**Recalling accurate science**
Conservation of matter			
Relate the environmental impact of garbage (e.g., the Great Pacific Garbage Patch, Wailingding Island, China) to the fact that matter is conserved. Write a proposal to address the problems and develop a presentation that includes evidence from research.	Make and test hypotheses about what will happen to the total mass during many types of changes (e.g., change in size, change in shape, change in arrangement of pieces, mixtures, solutions, ice melting, salt dissolving, paper tearing, candle burning, Alka-Seltzer in water, Lego building blocks).	Investigate what happens to mass in a closed system when changes occur in the system (e.g., dissolve salt in water, fill a balloon with baking soda and add it to vinegar in a bottle keeping the seal tight around the top of the bottle). Compare the mass of the system before and after the change.	Explain that the amount of matter stays constant during any change. Use an inflated balloon, at room temperature and after being cooled in a freezer, to support the claim that the mass of a gas stays the same as temperature changes.

Grade 4 continued

PHYSICAL SCIENCE (PS)

Topic: Electricity, Heat and Matter
This topic focuses on the conservation of matter and the processes of energy transfer and transformation, especially as they apply to heat and electrical energy.

CONTENT STATEMENT

4.PS.2: Energy can be transferred from one location to another or can be transformed from one form to another.

Energy transfers from hot objects to cold objects as heat, resulting in a temperature change.

Electric circuits require a complete loop of conducting materials through which electrical energy can be transferred.

Electrical energy in circuits can be transformed to other forms of energy, including light, heat, sound and motion. Electricity and magnetism are closely related.

CONTENT ELABORATION

Prior Concepts Related to Heat and Electricity
PreK-2: Temperature is a property of objects. Sunlight affects the warming or cooling of air, water and land. Charged objects can attract uncharged objects and may either attract or repel other charged objects. Magnetic objects can attract things made of iron and may either attract or repel other magnetic objects.

Grade 3: Objects that have energy can cause change. Heat, electrical energy, light, sound and magnetic energy are all forms of energy.

Grade 4 Concepts
Energy transfer (between objects or places) should not be confused with energy transformation from one form of energy to another (e.g., electrical energy to light energy). The addition of heat may increase the temperature of an object. The removal of heat may decrease the temperature of an object. There are materials in which the entire object becomes hot when one part of the object is heated (e.g., in a metal pan heat flows through the pan on the stove transferring the heat from the burner outside the pan to the food in the pan). There are other objects in which parts of the object remain cool even when another part of the object is heated (e.g., in a Styrofoam® cup, very little of the warmth from hot liquid inside the cup is transferred to the hand holding the cup).

The word "heat" is used loosely in everyday language, yet it has a very specific scientific meaning. Usually what is called heat is actually thermal or radiant energy. An object has thermal energy due to the random movement of the particles that make up the object. Radiant energy is that which is given off by objects through space (e.g., warmth from a fire, solar energy from the sun). "Heating" is used to describe the transfer of thermal or radiant energy to another object or place. Differentiating between heat, thermal energy and radiant energy is not appropriate at this grade. This document uses the same conventions as noted in the NAEP 2009 Science Framework (see page 29) where "heat" is used in lower grades. However, the word "heat" has been used with care so it refers to a transfer of thermal or radiant energy. Exploring heat transfer in terms of moving submicroscopic particles is not appropriate at this grade level.

Electrical conductors are materials through which electricity can flow easily. Electricity introduced to one part of the object spreads to other parts of the object (e.g., copper wire is an electrical conductor because electricity flows through the wires in a lamp from the outlet to the light bulb and back to the outlet). Electrical insulators are materials through which electricity cannot flow easily. Electricity introduced to one part of the object does not spread to other parts of the object (e.g., rubber surrounding a copper wire is an electrical insulator because electricity does not flow through the rubber to the hand holding it). Electrical conductivity is explored through testing common materials to determine their conductive properties. In order for electricity to flow through a circuit, there must be a complete loop through which the electricity can pass. When an electrical device (e.g., lamp, buzzer, motor) is not part of a complete loop, the device will not work. Electric circuits are introduced in the laboratory by testing different combinations of electrical components. When an electrical device is a part of a complete loop, the electrical energy can be transformed into light, sound, heat or magnetic energy. Electrical devices in a working circuit often get warmer.

When a magnet moves in relation to a coil of wire, electricity can flow through the coil. When a wire conducts electricity, the wire has magnetic properties and can push and/or pull magnets. The connections between electricity and magnetism can be explored in the laboratory through experimentation. Knowing the specifics of electromagnetism is not appropriate at this grade level. At this point, the connections between electricity and magnetism are kept strictly experiential and observational.

Future Application of Concepts
Grade 5: Light and sound are explored further as forms of energy.

Grades 6-8: Thermal energy is related to the atomic theory. Kinetic and potential energy are investigated. Conservation of energy and energy transfer through radiation, convection and conduction are studied. The transfer of electrical energy in circuits is investigated further.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Energy transfer			
Design and construct a device that accomplishes a task (e.g., causes a small cart to roll, pops a balloon, raises a flag, rings a bell) using a series of energy transfers between multiple objects (e.g., push a ball off a table so it falls on an object that releases a rubber band cart). Determine if energy would transfer to complete a system given a diagram of a possible energy transfer system (e.g., picture of a Rube Goldberg machine, mousetrap game). Explain why the system would or would not be successful. Explain what could be changed or altered to make the system more successful.	Investigate how changes to a simple electromagnet (e.g., more coils of wire, more batteries, different nails) affects the strength of its magnetic field (e.g., number of paper clips picked up, distance from which it can affect a paper clip).	Describe the energy transfers that occur between multiple objects in order for a device to accomplish a task (e.g., cause a small cart to roll, pop a balloon, raise a flag, ring a bell).	

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	Simple circuits		
Design and construct a switch that can activate a device (e.g., lighting a bulb or LED, running a motor, sounding a buzzer)	Analyze the differences between working and nonworking (open and closed) circuits and determine patterns and trends in the experimental evidence. Formulate a conceptual model of a working circuit based upon the trends in the experimental evidence. Test a variety of materials in a complete circuit. Explore which materials are electrical conductors and which materials are electrical insulators. Use results to identify similarities in materials that are conductors or materials that are insulators.	Represent the flow of energy through a circuit in which a power source is used to activate a device (e.g., using pictures, models, diagrams).	Identify the functions (e.g., conductor, insulator, energy source) of the components of a simple electric circuit. Explain that a working circuit requires a continuous loop of electrical conductors and a source of energy. Identify different types of energy conversions within an electrical circuit. Label the parts of a circuit.
	Heat energy		
Design an insulating device that will keep an object (e.g., ice cube, hot water, food) at a desired temperature. Collect and organize accurate data on the changes in temperature.	Investigate a variety of ways to heat food items (e.g., popcorn, hot dogs, marshmallows, chocolate, water). Collect and organize data on the changes in temperature. Evaluate the effectiveness of the heating methods.	Contrast thermal conductors and thermal insulators.	Measure the temperature of water. Recognize that an increase in temperature indicates an increase in thermal energy and a decrease in temperature indicates a decrease in thermal energy. Identify ways the temperature of an object can be changed (e.g., rubbing, heating, bending of metal). Explain in words and show in diagrams, pictures or models, the sources of thermal energy and the heat transfers that occur when heating a food item or a liquid.

Grade 4 continued

LIFE SCIENCE (LS)

Topic: Earth's Living History
This topic focuses on using fossil evidence and living organisms to observe that suitable habitats depend upon a combination of biotic and abiotic factors.

CONTENT STATEMENT	CONTENT ELABORATION
4.LS.1: Changes in an organism's environment are sometimes beneficial to its survival and sometimes harmful. Ecosystems can change gradually or dramatically. When the environment changes, some plants and animals survive and reproduce and others die or move to new locations. Ecosystems are based on interrelationships among and between biotic and abiotic factors. These include the diversity of other organisms present, the availability of food and other resources, and the physical attributes of the environment.	**Prior Concepts Related to Behavior, Growth and Changes** **PreK-2:** Plants and animals have variations in their physical traits that enable them to survive in a particular ecosystem. Living things that once lived on Earth no longer exist, as their needs were not met. Living things have basic needs, which are met by obtaining materials from the physical environment. **Grade 3:** Plants and animals have life cycles that are part of their adaptations for survival in their natural ecosystems. **Grade 4 Concepts** Ecosystems can change rapidly (e.g., volcanic activity, earthquakes, fire) or very slowly (e.g., climate change). Ohio has experienced various climate patterns. Glaciers covered parts of Ohio and other parts of Ohio were submerged with water as indicated by Ohio's fossil record. Major changes, both natural and human caused, over a short period of time can have significant impacts on ecosystems and populations of plants and animals. The changes that occur in the plant and animal populations can impact access to resources for the remaining organisms, which may result in migration or death. Specific ecosystems in Ohio (e.g., rivers, streams, meadows, bogs, lakes, moraines, other natural areas) can be researched and investigated via field studies and virtual field trips. The relationships between current and past ecosystems, the changes that have occurred over time in those ecosystems, and the species that lived there are explored. **Future Application of Concepts** **Grades 6-8:** Organisms that survive pass on their traits to future generations. Climate, rock record and geologic periods are explored.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	Changes in ecosystems		
Research the effects of an environmental change (e.g., deforestation, climate change, pollution, fire, drought, flooding, decreased oxygen levels) on organisms in an ecosystem. Develop a plan to help return an ecosystem back to its original state (e.g., remediation of riverbanks after a flood, reforestation) or prevent the return of an ecosystem back to its original state (e.g., damming the Mississippi River so it can't revert to its earlier course). Critique plans (written or oral) from different organizations to reintroduce a species into an Ohio ecosystem. Write a newspaper article in support or against the reintroduction of the species based upon scientific facts.	Using a streambed conduct an investigation to determine how erosion and deposition impact organisms in that ecosystem. Explore the effect of glaciation on our landforms by comparing northwestern Ohio with southeastern Ohio.	Use maps of Ohio over several time periods to investigate past and current ecosystems and the organisms that lived in each. Read a first-hand description and/or view drawings of Ohio ecosystems as first observed by explorers and compare the historical environmental descriptions to the current description. Explain changes that occurred in the biotic and abiotic components of the local ecosystem. Check with your local historical society and library for assistance in locating resources for your community. Examine the past ecosystems of your local community and create a visual representation (e.g. storyboard) showing the timeline of the change. Explain the anticipated impact of a change to the ecosystem (e.g., deforestation, fire, pollution, climate change, drought, flooding, decrease in oxygen levels) to the native species and surrounding area.	Describe major changes in Ohio's ecosystems over time and the organisms supported in each (e.g., oceanic, glacial, wetlands, forests).

Grade 4 continued

LIFE SCIENCE (LS)

Topic: Earth's Living History
This topic focuses on using fossil evidence and living organisms to observe that suitable habitats depend upon a combination of biotic and abiotic factors.

CONTENT STATEMENT

4.LS.2: Fossils can be compared to one another and to present-day organisms according to their similarities and differences.

The concept of biodiversity is expanded to include different classification schemes based upon shared internal and external characteristics of organisms.

Most species that have lived on Earth are extinct.

Fossils provide a point of comparison between the types of organisms that lived long ago and those existing today.

CONTENT ELABORATION

Prior Concepts Related to Behavior, Growth and Changes
PreK-2: Living things have basic needs, which are met by obtaining materials from the physical environment. Plants and animals have variations in their physical traits that enable them to survive in a particular ecosystem. Living things that once lived on Earth no longer exist, as their needs were not met.

Grade 3: Plants and animals have life cycles that are part of their adaptations for survival in their natural ecosystems.

Grade 4 Concepts
Fossils provide evidence that many plant and animal species are extinct and other species have changed over time. The types of fossils that are present provide evidence about the nature of an ecosystem at that time. As an ecosystem changed, so did the types of organisms that could survive in that ecosystem.

The opportunity to learn about an increasing variety of living organisms, both the familiar and the exotic, should be provided. The observations and descriptions of organisms should become more precise in identifying similarities and differences based upon observed structures. Emphasis can still be on external features; however, finer detail than before should be included. Hand lenses and microscopes should be routinely used. Microscopes are used not to study cell structure but to begin exploring the world of organisms that cannot be seen by the unaided eye. Non-Linnaean classification systems should be developed that focus on gross anatomy, behavior patterns, habitats and other features.

Future Application of Concepts
Grades 6-8: Diversity of species is explored in greater detail. Modern Cell Theory and rock formation are explored.

High School: The concepts of evolution and cell biology are explored.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Fossils			
		Use resources to identify types of fossils and infer the environmental conditions in which an organism may have existed. Classify fossils based on anatomical characteristics and infer behavior patterns and habitats. Research appropriate paleontology dig techniques, tools and procedures to conduct a small-scale simulated archaeological dig through several visually distinct varying layers of sediment.	Identify evidence that can be used to determine the existence of an organism.
Comparing organisms			
Create a reconstruction of an extinct animal using information from the fossil record and examples of animals alive today (e.g., reconstruct the body of a trilobite, including soft tissue, after exploring a trilobite fossil and a living pill bug).		Research the ancestors of an organism living today using fossil evidence. Compare the living organism with its ancestors (e.g., body structure, habitat).	Use fossil evidence to show that organisms existing today have similarities to organisms that lived long ago.

Grade 5

INTRODUCTION TO CONTENT STATEMENTS

GRADE BAND THEME: INTERCONNECTIONS WITHIN SYSTEMS

This theme focuses on helping students explore the components of various systems and then investigate dynamic and sustainable relationships within systems using scientific inquiry.

STRANDS

Strand Connections: Cycles on Earth, such as those occurring in ecosystems, in the solar system, and in the movement of light and sound result in describable patterns. Speed is a measurement of movement. Change in speed is related to force and mass. The transfer of energy drives changes in systems, including ecosystems and physical systems.

EARTH AND SPACE SCIENCE (ESS)	PHYSICAL SCIENCE (PS)	LIFE SCIENCE (LS)
Topic: Cycles and Patterns in the Solar System This topic focuses on the characteristics, cycles and patterns in the solar system and within the universe.	**Topic: Light, Sound and Motion** This topic focuses on the forces that affect motion. This includes the relationship between the change in speed of an object, the amount of force applied and the mass of the object. Light and sound are explored as forms of energy that move in predictable ways, depending on the matter through which they move.	**Topic**: **Interactions within Ecosystems** This topic focuses on foundational knowledge of the structures and functions of ecosystems.
CONDENSED CONTENT STATEMENTS		
5.ESS.1 The solar system includes the sun and all celestial bodies that orbit the sun. Each planet in the solar system has unique characteristics. **5.ESS.2** The sun is one of many stars that exist in the universe. **5.ESS.3** Most of the cycles and patterns of motion between the Earth and sun are predictable.	**5.PS.1** The amount of change in movement of an object is based on the mass of the object and the amount of force exerted. **5.PS.2** Light and sound are forms of energy that behave in predictable ways.	**5.LS.1** Organisms perform a variety of roles in an ecosystem. **5.LS.2** All of the processes that take place within organisms require energy.

NATURE OF SCIENCE GRADES 3-5

Nature of Science One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.	
Categories	**3-5**
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Observe and ask questions about the world that can be answered through scientific investigations. • Design and conduct scientific investigations using appropriate safety techniques. • Use appropriate mathematics, tools, and techniques to gather data and information. • Develop and communicate descriptions, models, explanations and predictions. • Think critically and ask questions about the observations and explanations of others. • Communicate scientific procedures and explanations. • Apply knowledge of science content to real-world challenges.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	• Science is both a body of knowledge and processes to discover new knowledge. • Science is a way of knowing about the world around us based on evidence from experimentation and observations. • Science assumes that objects and events occur in consistent patterns that are understandable through measurement and observation.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• People from many generations and nations contribute to science knowledge. • People of all cultures, genders, and backgrounds can pursue a career in science. • Scientists often work in teams. • Science affects everyday life. • Science requires creativity and imagination.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• Science develops theories based on a body of scientific evidence. • Science explanations can change based on new scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Complete *Nature of Science* document is found on pages 8-12.

Grade 5 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Cycles and Patterns in the Solar System
This topic focuses on the characteristics, cycles and patterns in the solar system and within the universe.

CONTENT STATEMENT

5.ESS.1: The solar system includes the sun and all celestial bodies that orbit the sun. Each planet in the solar system has unique characteristics.

The distance from the sun, size, composition and movement of each planet are unique. Planets revolve around the sun in elliptical orbits. Some of the planets have moons and/or debris that orbit them. Comets, asteroids and meteoroids orbit the sun.

CONTENT ELABORATION

Prior Concepts Related to Solar System

PreK-2: The moon, sun and stars can be observed at different times of the day or night. The observable shape of the moon changes throughout the month. The sun's position appears to change in a single day and from day to day. The sun is the principal source of energy. Earth's atmosphere is discussed.

Grades 3-4: All objects are made of matter. Light is a form of energy. Earth's surface is discussed and gravitational forces are introduced.

Grade 5 Concepts

Planets in the solar system orbit the sun. Some of the planets have one or more orbiting moons. Earth is a planet that has a moon. The moon orbits Earth. Gravitational forces between the sun and its planets cause the planets to orbit the sun. Gravitational forces between a planet and its moon(s) cause the moon(s) to orbit the planet. If no forces were present, planets and moons would continue their motion toward outer space without changes in speed or direction. However, gravitational forces between the sun and each planet continuously changes the planet's direction so it remains in orbit. In the same way, gravitational forces between each moon and its planet continuously changes the moon's direction so it remains in orbit.

Asteroids are rocky bodies that orbit the sun in nearly circular orbits but are too small to be classified as planets. Comets are a mixture of ices (e.g., water, methane, carbon monoxide, carbon dioxide, ammonia) and dust, and have highly elliptical orbits. A meteor appears when a particle or chunk of metallic or stony matter called a meteoroid enters Earth's atmosphere from outer space. Meteors that pass through the atmosphere and impact Earth's surface are called meteorites.

General information regarding planetary positions, orbital patterns, planetary composition and recent discoveries and projects (e.g., missions to Mars) are included in this content. Tools and technology are an essential part of understanding the workings within the solar system.

Future Application of Concepts

Grades 6-8: The interior and exterior composition of Earth, Earth's unique atmosphere, light waves, electromagnetic waves, interactions among Earth, moon and sun and gravitational forces are explored in more depth.

High School: Galaxies, stars and the universe are studied in the physical sciences.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Solar system			
Analyze various online models or student created models of the solar system. Critique the models on their ability to accurately depict the relationships among bodies in the solar system. Choose a planet (other than Earth) or a moon and research and develop a plan to colonize it with humans. Evaluate current conditions and what would be needed to meet the basic requirements for humans to live there. Critique the plan. Ask: Is the plan feasible? What equipment is required? Make a final recommendation based on the research. Present recommendations to the class.	Choose a major planet. Plan and build a scaled model that can demonstrate the planet size, rotation and orbit in relationship to the sun and Earth.	Use a flashlight or other light source as the sun to model various aspects of the sun and Earth movement relationships. Make a table, chart or graphic that interprets the general characteristics of the major planets in the solar system. Use real data (current) to compare the planets. Explore current scientific discussions about how to classify planets (e.g., dwarf vs. regular).	Explain the characteristics of major types of objects that orbit the sun (e.g., planets, comets, meteoroids, asteroids).

Grade 5 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Cycles and Patterns in the Solar System
This topic focuses on the characteristics, cycles and patterns in the solar system and within the universe.

CONTENT STATEMENT

5.ESS.2: The sun is one of many stars that exist in the universe.

The sun appears to be the largest star in the sky because it is the closest star to Earth. Some stars are larger than the sun and some stars are smaller than the sun.

CONTENT ELABORATION

Prior Concepts Related to Sun
PreK-2: The sun can be observed at different times of the day or night. The sun's position in the sky appears to change in a single day and from day to day. The sun is the principal source of energy.

Grades 3-4: All objects are made of matter. Heat and light are forms of energy. Gravitational forces are introduced.

Grade 5 Concepts
The sun is the closest star to Earth. Scaled models (3-D or virtual) and graphics can be used to show the vast difference in size between the sun and Earth. The sun is a medium-sized star and is the only star in our solar system. There are many other stars of different sizes in the universe. Because they are so far away, they do not appear as large as the sun. Stars appear in patterns called constellations, which can be used for navigation.

General facts about the size and composition of the sun are introduced. Details (e.g., age of the sun, specific composition, temperature values) are above grade level. The emphasis should be on general characteristics of stars and beginning to understand the size and distance of the sun in relationship to Earth and other planets.

Current and new discoveries related to the sun and other stars are included.

Future Application of Concepts
Grades 6-8: Earth's unique atmosphere, light waves, electromagnetic waves, interactions between Earth, moon and sun (including the phases of the moon and tides), and gravitational forces are explored in more depth.

High School: Galaxies, stars and the universe are studied in the physical sciences.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
The sun			
	Design and construct a model that shows the relationship between the size of the sun and Earth.	Differentiate between the sun and a red dwarf or blue giant star. Make a table or chart to represent the comparison. Research ways that constellations have been used for navigation throughout history.	Identify the sun as a medium-sized star and the only star in the solar system. Recall that there are many other stars in the universe and they are different sizes, but the sun appears larger because it is closer to Earth.

Grade 5 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Cycles and Patterns in the Solar System
This topic focuses on the characteristics, cycles and patterns in the solar system and within the universe.

CONTENT STATEMENT

5.ESS.3: Most of the cycles and patterns of motion between the Earth and sun are predictable.

Earth's revolution around the sun takes approximately 365 days. Earth completes one rotation on its axis in a 24-hour period, producing day and night. This rotation makes the sun, stars and moon appear to change position in the sky.

Note: *Moon phases should not be the focus.*

CONTENT ELABORATION

Prior Concepts Related to Earth, Sun and Moon
PreK-2: The sun and moon can be observed at different times of the day or night. The sun's position in the sky appears to change in a single day and from day to day. The observable shape of the moon changes throughout the month. The sun is the principal source of energy.

Grades 3-4: All objects are made of matter. Heat and light are forms of energy. Gravitational forces are introduced.

Grade 5 Concepts
In a day Earth rotates once on its axis, which is tilted at a 23.5° angle. Earth's rotation causes the apparent position of the sun, moon and stars to move in the sky from east to west. Some stars are visible from all parts of Earth, some stars can only be seen from the northern hemisphere and some stars can only be seen from the southern hemisphere. Stars located directly above the north and south poles do not appear to move. A well-known example of this is the North Star. The effects of Earth's tilt are not the focus at this level. Direct and indirect sunlight, the reason hours of daylight change throughout the year and the role of Earth's tilt in changing seasons are reserved for grade 7.

Shadows change throughout the day due to the apparent movement of the sun. This content can be linked with content from 5.PS.2.

As Earth orbits the sun, different stars and constellations are visible during different portions of the year. Stars located in the same direction as the sun are not visible because the sun is so bright compared to the other stars. Stars located in the direction opposite from the sun are seen during nighttime hours. As Earth moves in its orbit around the sun, various sections of the sky are visible during nighttime hours. This allows different stars to be seen at different times of the year.

Models, interactive websites and investigations are used to illustrate the predictable patterns and cycles that lead to the understanding of rotation (day and night) and revolution (years).

Future Application of Concepts
Grades 6-8: Earth's unique atmosphere, light waves, electromagnetic waves, interactions between Earth, moon and sun (including the phases of the moon and tides), seasons, climate studies and gravitational forces are explored in more depth.

High School: Galaxies, stars and the universe are studied in the physical sciences.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Cycles between Earth and the sun			
	Create a sundial and record different shadow positions throughout the day. Analyze the data. Discuss whether the results would be the same in a different global location (e.g., eastern hemisphere, southern hemisphere) or at a different time of year. Using a simple model, investigate the positions of the sun, moon and Earth to detect and test the reasons why the moon and sun appear to change position in the sky and why the moon has phases. Ask: If we were standing on the moon would Earth have phases?	Represent the sun, moon and Earth and their orbits graphically and to scale. Use actual data and measurements for the representation.	Recognize that the rotation of Earth on its axis produces day and night, which is why the sun, stars and moon appear to change position in the sky.

Grade 5 continued

PHYSICAL SCIENCE (PS)

Topic: Light, Sound and Motion

This topic focuses on the forces that affect motion. This includes the relationship between the change in speed of an object, the amount of force applied and the mass of the object. Light and sound are explored as forms of energy that move in predictable ways, depending on the matter through which they move.

CONTENT STATEMENT

5.PS.1: The amount of change in movement of an object is based on the mass of the object and the amount of force exerted.

Movement can be measured by speed. The speed of an object is calculated by determining the distance (d) traveled in a period of time (t).

Any change in speed or direction of an object requires a force and is affected by the mass of the object and the amount of force applied.

Note: *Differentiating between mass and weight is not necessary at this grade level.*

CONTENT ELABORATION

Prior Concepts Related to Force and Motion

PreK-2: Motion is described as a change in position. Forces are introduced as pushes and pulls. Forces are needed to change the motion of objects. Greater force on an object results in a greater change of motion.

Grades 3-4: Forces in nature are responsible for water movement, wind movement and movement of sediment through the process of erosion.

Grade 5 Concepts

The motion of an object can change by speeding up, slowing down or changing direction. Forces cause changes in motion. If a force is applied in the direction of an object's motion, the speed will increase. If a force is applied in the direction opposite an object's motion, the speed will decrease. The greater the force acting on an object, the greater the change in motion. The greater the mass of an object, the less influence a force will have on its motion. If no force acts on an object (or the forces are balanced), the object does not change its motion and moves at constant speed in a given direction. If an object is not moving and no force acts on it (or the forces are balanced), the object will remain at rest.

A force is described by its strength and the direction that it pushes or pulls an object. More than one force can act on an object at a time. At this grade level, only consider two forces acting on an object either horizontally or vertically. When two forces act on an object, their combined effect influences the motion of that object. The effect forces have on an object depends not only on the forces' strengths, but also on their directions. If the forces have equal strengths, but act in opposite directions, the object's motion will not change, and the forces are considered balanced. A stationary object subject to balanced forces will remain stationary. A moving object subject to balanced forces will continue moving in the same direction at the same speed. Unbalanced forces will cause change in the motion of an object. A stationary object subject to unbalanced forces will move in the direction of the larger force. Inquiry activities should be used to develop student understanding of the effects of forces on the motion of objects.

	Movement is a change in position. Speed is a measurement of how fast or slow this change takes place. In the same amount of time, a faster object moves a greater distance than a slower object. Speed is calculated by dividing distance traveled by elapsed time. An object that moves with constant speed travels the same distance in each successive unit of time. When an object is speeding up, the distance it travels increases with each successive unit of time. Speed should be investigated through testing and experimentation. When possible, real-world settings are recommended for the investigations. Virtual investigations, simulations and freeze-frame video also can be used to explore concepts of speed. **Note 2:** *While concepts are related to Newton's first and second laws, they should remain conceptual at this grade. Knowing the names of the laws is not required. Memorizing and reciting words to describe Newton's second law is not appropriate.* **Note 3:** *Although mathematics is applied to the concept of speed at this grade level, its use should support deeper understanding of the concept and not be taught as the primary definition of speed.* **Future Application of Concepts** **Grades 6-8:** Vectors are used to show the magnitude and direction of forces. Position vs. time graphs are used to represent motion. Fields are introduced for forces that act over a distance. **High School:** Newton's second law is used to solve mathematical problems in one and two dimensions. Speed vs. time graphs are used to represent motion.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Speed			
Design a system to determine the speed of a car. Give an example of how the speed could be calculated from the measurements.	Investigate the relationship between time, speed and distance. Describe patterns for objects moving at constant speed, objects slowing down and object speeding up.	Compare constant and changing speed by reading graphs, tables or using models.	Classify motion as constant speed, speeding up or slowing down based on distance traveled per unit of time. Describe the relationship between time, speed and distance. Identify examples of constant speed, speeding up and slowing down in everyday circumstances (e.g., vehicles traveling, people walking, predator/prey, sports). Use distance traveled in a period of time to calculate speed.
Balanced and unbalanced forces			
	Explore a variety of balanced and unbalanced forces on objects. Identify the forces involved. Describe the strength and direction of the forces and the effect they have on the motion of the objects.	Identify forces based on real life examples found in games and everyday activities (e.g., bowling, baseball, kickball). Identify them as balanced or unbalanced. Design demonstrations to show the effects of balanced and unbalanced forces on objects.	Classify pairs of forces acting on an object as balanced or unbalanced when given various scenarios.
How mass affects motion			
	Investigate the effect of mass on the force required to move an object (e.g., vary the mass of an object and observe the effect of the same force on that object).		Explain that objects with less mass travel farther than those with more mass when pushed with the same force.

Grade 5 continued

PHYSICAL SCIENCE (PS)

Topic: Light, Sound and Motion
This topic focuses on the forces that affect motion. This includes the relationship between the change in speed of an object, the amount of force applied and the mass of the object. Light and sound are explored as forms of energy that move in predictable ways, depending on the matter through which they move.

CONTENT STATEMENT

5.PS.2: Light and sound are forms of energy that behave in predictable ways.

Light travels and maintains its direction until it interacts with an object or moves from one medium to another and then it can be reflected, refracted or absorbed.

Sound is produced by vibrating objects and requires a medium through which to travel. The rate of vibration is related to the pitch of the sound.

Note: *At this grade level, the discussion of light and sound should be based on observable behavior. Waves are introduced at the middle school level.*

CONTENT ELABORATION

Prior Concepts Related to Light and Sound
PreK-2: Sound is related to vibrations. The moon, sun and stars are visible at different times. The sun is the principal source of energy. Sunlight affects the warming and cooling of air, water and land.

Grades 3-4: Objects with energy can cause motion or create change. Energy can transfer between objects and locations. Light energy from the sun contributes to plant growth.

Grade 5 Concepts
Light can travel through some materials, such as glass or water. Light can also travel through empty space, like from the sun to Earth. When light travels from one location to another, it goes in a straight line until it interacts with another object or material. When light strikes objects through which it cannot pass, shadows are formed. As light reaches a new material, it can be absorbed, refracted, reflected or can continue to travel through the new material; one of these interactions may occur or many may occur simultaneously, depending on the material.

Light can be absorbed by objects, causing them to warm. How much an object's temperature increases depends on the material of the object, the intensity of and the angle at which the light strikes its surface, how long the light shines on the object and how much light is absorbed. Investigating and experimenting with temperature changes caused by light striking different surfaces can be virtual or in a lab setting.

When light passes from one material to another, it is often refracted at the boundary between the two materials and travels in a new direction through the new material (medium). For example, a magnifying lens bends light and focuses it toward a single point. A prism bends white light and separates the different colors of light. Prisms and magnifying lenses can be used to observe the refraction of light.

Visible light can be emitted from an object (like the sun) or reflected by an object (like a mirror or the moon). The reflected colors are the only colors visible when looking at an object. For example, a red apple looks red because the red light that hits the apple is reflected while the other colors are absorbed. The additive rules for color mixing of light, other than the fact that white light is a mixture of many colors, are reserved for later grades. The wave nature of sound and light are not introduced at this level nor are parts of the electromagnetic spectrum other than visible light.

Pitch can be altered by changing how fast an object vibrates. Objects that vibrate slowly produce low pitches; objects that vibrate quickly produce high pitches. Audible sound can only be detected within a certain range of pitches. Sound must travel through a material (medium) to move from one place to another. This medium may be a solid, liquid or gas. Sound travels at different speeds through different media. At this grade, how sound travels through the medium is not appropriate as atoms and molecules are not introduced until grade 6.

Once sound is produced, it travels outward in all directions until it reaches a different medium. When it encounters this new medium, the sound can continue traveling through the new medium, become absorbed by the new medium, bounce back into the original medium (reflect) or engage in some combination of these possibilities.

Light travels faster than sound. Technology, virtual simulations and models can help demonstrate the movement of light and sound. Experimentation, testing and investigation (3-D or virtual) are essential components of learning about light and sound properties.

Future Application of Concepts
Grades 6-8: The atomic nature of matter is introduced and energy is classified as kinetic and potential. Waves are introduced. Energy transfer and transformation, and conservation of energy are explored further.

High School: The wave nature of light and sound is expanded upon including mathematical analysis of wavelength, frequency, and speed, as well as the Doppler effect.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Reflection and absorption			
Design a shelter for daytime use on hot sunny days. Design the shelter so that it keeps the inside temperature as cool as possible.	Compare temperatures of a substance (e.g., water, sand) that is heated by a light shining on it at different angles or intensities. Describe the relationship between the angle and the change in temperature.	Explain how we see color due to the reflection and absorption of light.	Identify sources of light as emitted or reflected.
Refraction			
		Demonstrate the refraction of light that results in the separation of colors using a flashlight and prism (or the sun and bubbles).	
Transparent, translucent, and opaque			
Create a model/illustration of a building and explain the usefulness of different materials in the design with relationship to light energy. Identify locations where transparent, translucent and opaque materials are appropriate.		Model the amount of light that can pass through a transparent, translucent or opaque material.	Classify a set of objects as transparent, translucent and opaque.

Grade 5 continued

LIFE SCIENCE (LS)

Topic: Interconnections within Ecosystems
This topic focuses on foundational knowledge of the structures and functions of ecosystems.

CONTENT STATEMENT

5.LS.1: Organisms perform a variety of roles in an ecosystem.

Populations of organisms can be categorized by how they acquire energy.

Food webs can be used to identify the relationships among producers, consumers and decomposers in an ecosystem.

CONTENT ELABORATION

Prior Concepts Related to Interactions within Environments
PreK-2: Plants get energy from sunlight. Animals get energy from plants and other animals. Living things cause changes on Earth.

Grade 5 Concepts
The content statements for fifth-grade life science are each partial components of a larger concept. The parts have been isolated to call attention to the depth of knowledge required to build to one of biology's foundational theories: dynamic relationships within ecosystems. It is recommended that the content statements be combined and taught as a whole. For example, it is important that the ecological role of organisms is interwoven with a clear understanding that all living things require energy.

Plants and some microorganisms are producers. They are the foundation of the food web. Producers transform energy from the sun and make food through a process called photosynthesis. Animals get their energy by eating plants and other animals that eat plants. Animals are consumers and many form predator-prey relationships. Decomposers (primarily bacteria and fungi) are consumers that use waste materials and dead organisms for food. Decomposers also return nutrients to the ecosystem.

One way that ecosystem populations interact is centered on relationships for obtaining energy. Food webs are defined in many ways, including as a scheme of feeding relationships, which resembles a web. This web serves as a model for feeding relationships of member species within a biological community. Members of a species may occupy different positions during their lives. Food chains and webs are schematic representations of real-world interactions. For this grade level, it is enough to recognize that food webs represent an intertwining of food chains within the same biological community.

Organisms have symbiotic relationships in which individuals of one species are dependent upon individuals of another species for survival. Symbiotic relationships can be categorized as mutualism (where both species benefit), commensalism (where one species benefits and the other is unaffected), and parasitism (where one species benefits and the other is harmed).

Investigations of locally threatened or endangered species can be conducted and include considerations of the effects of remediation programs, species loss and the introduction of new species on the local ecosystem.

Note: *At this grade, species can be defined by using Ernst Mayer's definition "groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups."*

Future Application of Concepts
Grades 6-8: The importance of biodiversity within an ecosystem is explored.

High School: The concepts of evolution and biodiversity are explored.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Interactions in ecosystems			
Design and build a self-sustaining habitat (e.g., terrarium, bottle biology). Considerations for the habitat include the size of the container, location to create the proper temperature, light and humidity, and organisms that will support one another.		Observe the interaction of two organisms in an ecosystem or on a video. Determine whether they have a symbiotic relationship and, if so, decide which type of symbiotic relationship exists. Support your claim with evidence. Compare a predator-prey relationship to parasitism. Compare the roles of producers, consumers and decomposers and explain how they work together within an ecosystem.	Given a list of organisms and a description of their interactions within an ecosystem, classify them as producers, consumers, or decomposers. Given a list of organisms and a description of their interactions within an ecosystem, recognize and identify examples of symbiosis (e.g., mutualism, commensalism and parasitism).

Grade 5 continued

LIFE SCIENCE (LS)

Topic: Interconnections within Ecosystems
This topic focuses on foundational knowledge of the structures and functions of ecosystems.

CONTENT STATEMENT	CONTENT ELABORATION
5.LS.2: All of the processes that take place within organisms require energy. For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred and transformed by producers into energy that organisms use through the process of photosynthesis. That energy is used or stored by the producer and can be passed from organism to organism as illustrated in food webs.	**Prior Concepts Related to Interactions within Environments** **PreK-2:** Living things have basic needs, which are met by obtaining materials from physical ecosystems. **Grade 5 Concepts** The content statements for fifth-grade life science are each partial components of a larger concept. The parts have been isolated to call attention to the depth of knowledge required to build to one of biology's foundational theories: dynamic relationships within ecosystems. It is recommended that the content statements be combined and taught as a whole. For example, it is important that the ecological role of organisms is interwoven with a clear understanding that all living things require energy. Virtual simulations and investigations can help demonstrate energy flow through the trophic levels. Energy flows through an ecosystem in one direction, from the sun to photosynthetic organisms to consumers (herbivores, omnivores, carnivores) and decomposers. The exchange of energy that occurs in an ecosystem can be represented as a food web. The exchange of energy in an ecosystem is essential because all processes of life for all organisms require a continual supply of energy. Direct and remote sensing (e.g., satellite imaging and other digital-research formats) can be used to help visualize what happens in an ecosystem when new producers, including invasive species, enter an ecosystem. The information gained should be used to determine the relationship between the producers and consumers within an ecosystem. **Future Application of Concepts** **Grades 6-8:** Concepts will build for an understanding of the interdependencies and interrelationships of organisms that are required to build stability in an ecosystem. **High School:** The details of photosynthesis are addressed in Biology.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Organisms acquire and use energy			
	Design an investigation that will measure changes in heart rate related to physical activity or exercise.	Research how the muscular, respiratory and cardiovascular systems work together during physical activity and relate to energy use.	Given a list of common organisms and a description of their interactions in an ecosystem, draw a food web using arrows to illustrate the flow of energy. Properly identify the producers and consumers.
Ecosystem changes			
Critique a plan to reintroduce a species into an Ohio ecosystem (e.g., sauger, salamander, sturgeon, northern riffleshell mussel). Provide evidence to support or oppose the reintroduction of the species based upon scientific facts.		Explain the effects of altering specific factors (e.g., number of predators, rainfall, invasive species) in an ecosystem and the effect it has on organisms. Explain ways that humans can improve the health of ecosystems (e.g., recycling wastes, establishing rain gardens, planting native species).	Describe how an invasive species can be harmful to an ecosystem.

Grade 6

INTRODUCTION TO CONTENT STATEMENTS

GRADE BAND THEME: ORDER AND ORGANIZATION

This theme focuses on helping students use scientific inquiry to discover patterns, trends, structures and relationships that may be inferred from simple principles. These principles are related to the properties or interactions within and between systems.

STRANDS

Strand Connections: All matter is made of small particles called atoms. The properties of matter are based on the order and organization of atoms and molecules. Cells, minerals, rocks and soil are all examples of matter.

EARTH AND SPACE SCIENCE (ESS)	PHYSICAL SCIENCE (PS)	LIFE SCIENCE (LS)
Topic: Rocks, Minerals and Soil This topic focuses on the study of rocks, minerals and soil, which make up the lithosphere. Classifying and identifying different types of rocks, minerals and soil can decode the past environment in which they formed.	**Topic: Matter and Motion** This topic focuses on the study of foundational concepts of the particulate nature of matter, linear motion, and kinetic and potential energy.	**Topic: Cellular to Multicellular** This topic focuses on the study of the basics of Modern Cell Theory. All organisms are composed of cells, which are the fundamental unit of life. Cells carry on the many processes that sustain life. All cells come from pre-existing cells.
CONDENSED CONTENT STATEMENTS		
6.ESS.1 Minerals have specific, quantifiable properties. **6.ESS.2** Igneous, metamorphic and sedimentary rocks have unique characteristics that can be used for identification and/or classification. **6.ESS.3** Igneous, metamorphic and sedimentary rocks form in different ways. **6.ESS.4** Soil is unconsolidated material that contains nutrient matter and weathered rock. **6.ESS.5** Rocks, mineral and soils have common and practical uses.	**6.PS.1** Matter is made up of small particles called atoms. **6.PS.2** Changes of state are explained by a model of matter composed of particles that are in motion. **6.PS.3** There are two categories of energy: kinetic and potential. **6.PS.4** An object's motion can be described by its speed and the direction in which it is moving.	**6.LS.1** Cells are the fundamental unit of life. **6.LS.2** All cells come from pre-existing cells. **6.LS.3** Cells carry on specific functions that sustain life. **6.LS.4** Living systems at all levels of organization demonstrate the complementary nature of structure and function.

NATURE OF SCIENCE GRADE 6-8

Nature of Science
One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.

Categories	6-8
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Apply knowledge of science content to real-world challenges. • Identify questions that can be answered through scientific investigations. • Design and conduct scientific investigations using appropriate safety techniques. • Use appropriate mathematics, tools and techniques to gather data and information. • Analyze and interpret data. • Develop descriptions, models, explanations and predictions. • Think critically and logically to connect evidence and explanations. • Recognize and analyze alternative explanations and predictions. • Communicate scientific procedures and explanations. • Design technological/engineering solutions.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	• Science is a way of knowing about the world around us based on evidence from experimentation and observations. • Science is a continual process and the body of scientific knowledge continues to grow and change. • Science assumes that objects and events occur in consistent patterns that are understandable through measurement and observation. • Science should carefully consider and evaluate all data including outliers. • Science is based on observable phenomena and empirical evidence. • Science disciplines share common rules for obtaining and evaluating empirical evidence.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• Individuals from different social, cultural, and ethnic backgrounds work as scientists and engineers. • Scientists and engineers are guided by habits of mind, such as intellectual honesty, tolerance of ambiguity, skepticism and openness to ideas. • Scientists and engineers rely on human qualities such as persistence, precision, reasoning, logic, imagination and creativity.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• Science explanations are subject to revision and improvement in light of additional scientific evidence or new understanding of scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Complete *Nature of Science* document is found on pages 8-12.

Grade 6 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Rocks, Minerals and Soil
This topic focuses on the study of rocks, minerals and soil, which make up the lithosphere. Classifying and identifying different types of rocks, minerals and soil can decode the past environment in which they formed.

CONTENT STATEMENT	CONTENT ELABORATION
6.ESS.1: Minerals have specific, quantifiable properties. Minerals are naturally occurring, inorganic solids that have a defined chemical composition. Minerals have properties that can be observed and measured. Minerals form in specific environments. **Note:** *The emphasis is on learning how to identify the mineral by conducting tests (not through memorization).*	**Prior Concepts Related to Mineral Properties** **PreK-2:** Objects have physical properties. Properties of objects can change. Earth's nonliving resources have specific properties. **Grades 3-5:** Rocks and soil have characteristics. Soil contains pieces of rocks. Objects are composed of matter and may exhibit electrical conductivity and magnetism. **Grade 6 Concepts** Most rocks are composed of one or more minerals. Minerals have specific properties that can be used for identification. The properties that can be used for testing minerals include luster, hardness, cleavage, streak, magnetism, fluorescence and/or crystal shape. At this grade level, common minerals (including those on Mohs hardness scale) are used in the identification process. A representative sample of minerals should be used so that different testing methods can be applied and demonstrated. Appropriate tools and safety procedures must be used when testing mineral properties. Technology can provide identification information and research materials to assist in mineral investigations. Mineral composition can help identify rocks. Minerals can indicate the type of environment in which the rock and/or mineral formed. Some minerals (e.g., feldspar varieties, magnetite, varieties of quartz) form in an igneous environment, some minerals (e.g., epidote) form in a metamorphic environment, and some form in a sedimentary environment (e.g., chalk, calcite). Some minerals (e.g., halite, varieties of gypsum, calcite) form through evaporation and a variety of chemical processes. **Future Application of Concepts** **Grades 7-8:** Biogeochemical cycles, igneous environments and the history of Earth (including the changing environments) from the interpretation of the rock record are studied. **High School:** The formation of elements, chemical bonding and crystal structure are found in the physical sciences. In Physical Geology, mineralogy is explored in depth.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	Minerals		
Given a variety of minerals design an investigation to determine the best one to use to polish a surface (e.g., make an arrowhead, sand wood, polish marble).	Simulate the formation of halite or gypsum in the Lake Erie area. Using data from the evaporate simulation predict how long it took to form the existing formations.	Explain the likely environmental conditions that existed when a specified mineral was formed based on its properties (e.g., halite and gypsum in the Lake Erie area). Make a dichotomous key of mineral properties for testing and identifying minerals. Compare rocks and minerals.	Identify properties, using tests, of common rock-forming minerals (e.g., calcite, halite, dolomite, gypsum, quartz, feldspar, mica, talc, kaolinite, chalk, topaz, corundum, pyrite, magnetite, epidote, hornblende). Sort minerals by identifying common properties such as luster, hardness, streak, cleavage, magnetism, fluorescence and/or crystal shape. Identify the different processes and/or environments in which minerals can form (e.g., evaporation, chemical processes, sedimentary, igneous or metamorphic). Explain that minerals have measurable properties that can be used for identification and/or classification.

Grade 6 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Rocks, Minerals and Soil
This topic focuses on the study of rocks, minerals and soil, which make up the lithosphere. Classifying and identifying different types of rocks, minerals and soil can decode the past environment in which they formed.

CONTENT STATEMENT	CONTENT ELABORATION
6.ESS.2: Igneous, metamorphic and sedimentary rocks have unique characteristics that can be used for identification and/or classification. Most rocks are composed of one or more minerals, but there are a few types of sedimentary rocks that contain organic material, such as coal. The composition of the rock, types of mineral present, and/or mineral shape and size can be used to identify the rock and to interpret its history of formation, breakdown (weathering) and transport (erosion).	**Prior Concepts Related to Rocks** **PreK-2:** Objects have physical properties. Properties of objects can change. Earth's nonliving resources have specific properties. **Grades 3-5:** Rocks and soil have characteristics. Soil contains pieces of rocks. Rocks form in different ways. Objects are composed of matter and may exhibit electrical conductivity and magnetism. **Grade 6 Concepts** The purpose of rock identification is related to understanding the environment in which the rock formed. Rock identification and classification are experiential and investigative. Common samples to use in identification should be representative of each type of rock. Igneous samples include varieties of granite, rhyolite, basalt, obsidian, pumice and andesite. Metamorphic samples include varieties of schist, gneiss, slate, marble, anthracite and phyllite. Sedimentary samples include varieties of limestone, sandstone, shale, conglomerate and breccia. Other rock samples such as bituminous coal, coquina and chert can also be included in identification investigations, but these may not always fall neatly into one specific rock category. Proper safety protocol and testing procedures must be used. It is important to use the identification of the minerals and quantifiable characteristics of the rock to identify the rock. Analysis of specific rock characteristics can be conducted in the classroom or in nature with rock samples. Technology can be used to research current identification methods and techniques to assist in determining the quantifiable characteristics of specific rocks. **Future Application of Concepts** **Grades 7-8:** Sedimentary, metamorphic and igneous environments, and the history of Earth (including the changing environments) from the interpretation of the rock record are studied. **High School:** The formation of elements, chemical bonding and crystal structure are found in the physical sciences. In Physical Geology, depositional environments, volcanism, characteristics of rocks and mineralogy are explored in depth.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Rocks			
Determine the best mineral or rock to use to solve a problem (e.g., neutralize acidic soil, make a statue). Evaluate the results and use the data to draw a conclusion.		Analyze the characteristics of rocks used locally (e.g., in landscape projects, buildings, floors, statues, gravestones, patios/walls). Make a chart, table or key to use in the classification of common rocks within each division of rock (sedimentary, igneous, metamorphic).	Recognize that each type of rock has a unique history based upon the environmental conditions that existed when it formed.

Grade 6 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Rocks, Minerals and Soil
This topic focuses on the study of rocks, minerals and soil, which make up the lithosphere. Classifying and identifying different types of rocks, minerals and soil can decode the past environment in which they formed.

CONTENT STATEMENT	CONTENT ELABORATION
6.ESS.3: Igneous, metamorphic and sedimentary rocks form in different ways. Magma or lava cools and crystallizes to form igneous rocks. Heat and pressure applied to existing rock forms metamorphic rocks. Sedimentary rock forms as existing rock weathers chemically and/or physically and the weathered material is compressed and then lithifies. Each rock type can provide information about the environment in which it was formed.	**Prior Concepts Related to Rocks** **PreK-2:** Objects have physical properties. Properties of objects can change. Earth's nonliving resources have specific properties. **Grades 3-5:** Rocks and soil have characteristics. Soil contains pieces of rocks. Rocks form in different ways. Objects are composed of matter and may exhibit electrical conductivity and magnetism. **Grade 6 Concepts** Rocks and minerals in rocks form in specific types of environments. The rock cycle can be used for a general explanation of the conditions required for igneous, metamorphic and sedimentary rocks to form, but additional information should be added for relevancy. For example, the typical pattern of coal formation is connected to energy in Ohio and should be included. Another example would be the formation of Ohio sandstone and limestone indicating that a shallow sea once covered Ohio. Ohio's geologic history and past environmental conditions play a role in understanding the existing bedrock in Ohio. Field investigations, virtual field trips, geologic maps, physical maps and topographic maps can be used to illustrate how types of geologic structures and features help identify the types of rock that may be found in specific areas. This should be connected to an understanding of the environmental conditions that existed during the formation. **Future Application of Concepts** **Grades 7-8:** Sedimentary, metamorphic and igneous environments, and the history of Earth (including the changing environments) from the interpretation of the rock record are studied. **High School:** The formation of elements, chemical bonding and crystal structure are found in the physical sciences. In Physical Geology, depositional environments, volcanism, characteristics of rocks and mineralogy are explored in depth. In Environmental Science, geological events and processes are explored as related to the lithosphere.

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Igneous, metamorphic and sedimentary rocks			
Make a geologic map of the local community. Use existing geologic data and field exploration to analyze types of formations/deposits that are present. Use the finished map to evaluate possible land and resource uses.	Based on the environment required for specific rock types to form, develop a hypothesis regarding the geologic history of a specific region. Cite evidence to support the hypothesis.	Use a geologic map of a region to determine what types of rocks are represented (igneous, sedimentary, metamorphic). Explain why those types of rocks might be found in that area. Compare multiple rock samples and hypothesize the environment or conditions in which they likely formed.	Identify the main processes of the rock cycle. Illustrate the process of formation of igneous, sedimentary, and metamorphic rock. Identify the likely environments or conditions of formation of igneous, sedimentary, and metamorphic rocks.

Grade 6 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Rocks, Minerals and Soil
This topic focuses on the study of rocks, minerals and soil, which make up the lithosphere. Classifying and identifying different types of rocks, minerals and soil can decode the past environment in which they formed.

CONTENT STATEMENT

6.ESS.4: Soil is unconsolidated material that contains organic matter and weathered rock.

Soil formation occurs at different rates and is based on environmental conditions, types of existing bedrock and rates of weathering. Soil forms in layers known as horizons. Soil horizons can be distinguished from one another based on properties that can be measured. The terms dirt and soil are not synonymous, use the term "soil".

Note: *The emphasis should be on properties of soil rather than memorization.*

CONTENT ELABORATION

Prior Concepts Related to Soil
PreK-2: Objects have physical properties. Properties of objects can change. Earth's nonliving resources have specific properties.

Grades 3-5: Rocks and soil have characteristics. Soil contains pieces of rocks. Soil investigations measure color, texture, ability for water to pass through soil, moisture content and soil composition. Objects are composed of matter.

Grade 6 Concepts
Soil sampling and testing should be used to investigate soil. Soils form at different rates and has different measurable properties, depending on environmental conditions. Properties of soil that are useful in soil identification include texture, color, composition, permeability and porosity. Uses of soils depend upon their properties. For example, some soils may be recommended for agriculture, while others may be used for brick making or creating a pond.

Observing and identifying soil horizons are based on understanding the different properties of soil and when the properties change. Soil sample testing methodology and equipment are included within this content statement. Soil maps combined with geologic, aerial or topographic maps can assist in local identification of soil formations. A connection can be made to environmental conditions, types of bedrock and soil properties.

Appropriate tools and safety procedures must be used in all soil investigations.

Future Application of Concepts
Grades 7-8: Biogeochemical cycles and the role of soil within them, soil erosion and runoff issues, hydrologic cycle including percolation and infiltration rates, and sedimentary environments are studied.

High School: The formation of elements, the importance of soil in an ecosystem, and issues with soil degradation and soil loss are explored. In Physical Geology, depositional environments, soil mechanics, issues with mass movement including soil/sediment contamination issues and the classification of soil is found.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Soil			
During some flooding events, sandbags are used to slow or redirect floodwaters. Develop a list of criteria required for the bags. Using four or five soil samples, design and conduct an investigation to determine which soil is best to use inside the sandbags. Analyze the soil data and test results to make the final determination.	Compare a specific and identifiable soil horizon in different locations within a community. Compare the depth of the soil horizons. Explain the differences that are measured. Identify appropriate land uses for each location. Plan and implement an investigation to determine which types of soil (e.g., sand, clay, loam, silt, gravel) are most likely to fail in a landslide event. Analyze the data and write a conclusion.	Discuss how soil depletion impacts different soil horizons which in turn impact the environment (e.g., the dust bowl, desertification, mass movement, erosion).	Identify the properties that can be measured in soil. Identify the characteristics of each horizon that makes up soil. Compare the different soil horizons (O, A, B and C) using the standard composition of each. Identify the types of conditions that may contribute to the formation of soil or lack of formation of soil. Use tools to measure soil characteristics and properties (e.g., permeability, porosity, texture, color).

Grade 6 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Rocks, Minerals and Soil
This topic focuses on the study of rocks, minerals and soil, which make up the lithosphere. Classifying and identifying different types of rocks, minerals and soil can decode the past environment in which they formed.

CONTENT STATEMENT	CONTENT ELABORATION
6.ESS.5: Rocks, minerals and soils have common and practical uses. Nearly all manufactured material requires some kind of geologic resource. Most geologic resources are considered nonrenewable. Rocks, minerals and soil are examples of geologic resources that are nonrenewable.	**Prior Concepts Related to Rocks, Minerals and Soil** **PreK-2:** Objects have physical properties. Properties of objects can change. Earth's nonliving resources have specific properties. **Grades 3-5:** Rocks and soil have characteristics. Earth's resources can be used for energy. Earth has renewable and nonrenewable resources, some of which are limited. **Grade 6 Concepts** Rocks, minerals and soils have specific physical properties that determine how they can be used. The different methods of extracting the resources can be included. Uses of the resources include construction (e.g., gypsum, metals, gravel, sand, lime, clay), energy (e.g., fossil fuels, radioactive materials), transportation (e.g., road salt, road materials), agriculture (e.g., lime, peat, minerals for fertilizers), domestic use (e.g., metals and gems for jewelry, clay for pottery or sculpting, natural dyes for clothing or paint) and technology (e.g., lithium, silica). The conservation of resources through their management is an important part of understanding the uses of rocks, minerals and soil. Aspects to consider include extraction methods and remediation of the sites and resource use, reuse, storage and disposal. Nonrenewable energy sources can also be included (such as fossil fuels). **Future Application of Concepts** **Grades 7-8:** Biogeochemical cycles (including the hydrologic cycle) are related to erosion and weathering of rock, minerals and soil. The history of Earth (including the formation of fossil fuels) from the interpretation of the rock record is studied. **High School:** The formation of elements, chemical bonding and nuclear energy are found in the physical sciences. In Physical Geology, Earth's resources and specific laws pertaining to the resources are explored at a greater depth. In Environmental Science, geological events and processes are explored as related to the lithosphere.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Uses of geologic resources			
During some flooding events, sandbags are used to slow or redirect floodwaters. Develop a list of criteria required for the bags. Using four or five soil samples, design and conduct an investigation to determine which soil is best to use inside the sandbags. Analyze the soil data and test results to make the final determination.	Plan and implement an investigation to determine which type of soil (e.g., sand, clay, loam, silt, gravel) is most appropriate for a particular construction project (e.g. housing development, park, levee, pond). Analyze the data and write a conclusion.	Make a map or 3-D model of Ohio that illustrates the major geologic resources that are found. Share the final product with the class.	Identify examples of different ways that soil, rocks and minerals can be used.

Grade 6 continued

PHYSICAL SCIENCE (PS)

Topic: Matter and Motion

This topic focuses on the study of foundational concepts of the particulate nature of matter, linear motion, and kinetic and potential energy.

CONTENT STATEMENT

6.PS.1: Matter is made up of small particles called atoms.

Matter has mass, volume and density and is made up of particles called atoms.

Elements are a class of substances composed of a single kind of atom.

Molecules are the combination of two or more atoms that are joined together chemically.

CONTENT ELABORATION

Prior Concepts Related to Matter

PreK-2: Properties are attributes that can be observed using the senses. Materials can be sorted according to their properties. Changes in materials are investigated.

Grades 3-5: Objects are composed of matter, which has mass and takes up space. Matter includes solids, liquids and gases (air). Volume is the amount of space an object occupies. The total amount of matter and mass remains the same when it undergoes a change.

Grade 6 Concepts

Matter is made of atoms, which are particles that are too small to be seen, even with a light microscope. Matter has properties of mass and volume. Mass measures the amount of matter in an object (e.g., a wood block) or substance (e.g., water), and volume measures the three-dimensional space that matter occupies. Mass can be measured with a balance. The volume of solids can be determined by water displacement or calculated from the dimensions of a regular solid.

Equal volumes of different substances usually have different masses. Some materials, like lead or gold, have a lot of mass in a relatively small space. Other materials, like packing peanuts and air, have a small mass in a relatively large amount of space. This concept of comparing substances by the amount of mass the substance has in a given volume is known as density. While the mass and volume of a material can change depending upon how much of the material there is, the density generally remains constant, no matter how much of the material is present. Therefore, density can be used to identify a material. Mass vs. volume graphs can be constructed and interpreted to determine which material has the greater density. Mathematical calculations of density are not the focus at this grade level and should be delayed until students have a conceptual understanding of density.

An element is a chemical substance that cannot be broken down into simpler substances. There are approximately 90 different naturally occurring elements that have been identified. There are additional elements that were made in a laboratory, but these elements are not stable. All atoms of any one element are alike but are different from atoms of other elements. Atoms of elements can join together to form molecules.

Note: *The structure of the atom, including protons, neutrons and electrons, is not the focus at this grade level; it is addressed in high school physical sciences.*

Future Application of Concepts
Grades 7-8: Differences between pure substances and mixtures are explored. Elements in the periodic table can be classified as a metal, nonmetal or metalloid based on their properties and position on the periodic table. Atoms can be joined together to form separate molecules or large three-dimensional networks.

High School: Protons, neutrons and electrons make up atoms. The relationship between atomic structure and the periodic table is explored. The nature of ionic, covalent and metallic bonding is also studied. Acids and bases are explored.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Matter			
Design and construct a device (e.g., lava lamp) to demonstrate the relationship between temperature and density.	Devise a method to prove or disprove the statement "*The density of a given substance remains constant.*" Share evidence to support your conclusion.	Graph mass vs. volume for water and a variety of other substances to compare their densities.	Define mass, volume, and density of an object. Using two objects with either the same mass or the same volume, explain conceptually which object has a greater density. Explain the relationship between elements and molecules.

Grade 6 continued

PHYSICAL SCIENCE (PS)

Topic: Matter and Motion
This topic focuses on the study of foundational concepts of the particulate nature of matter, linear motion, and kinetic and potential energy.

CONTENT STATEMENT	CONTENT ELABORATION
6.PS.2: Changes of state are explained by a model of matter composed of particles that are in motion. Temperature is a measure of the average motion of the particles in a substance. Heat is a process of energy transfer rather than a type of energy. Energy transfer can result in a change in temperature or a phase change. When substances undergo changes of state, atoms change their motion and position. **Note:** *It is not the intent of this standard to encourage vocabulary identification (matching definitions with heat, temperature, and thermal energy). Instead, these are provided as conceptual tools for understanding the role of energy in physical, biotic, atmospheric, oceanic, and geologic systems covered in grade 6 and subsequent grades and courses.*	**Prior Concepts Related to Matter** **PreK-2:** Properties can be observed and used to sort materials. Changes in materials are investigated, including solid-liquid phase changes. **Grades 3-5**: Matter has mass and volume. The total amount of matter remains the same when it undergoes a change. Properties of solids, liquids and gases are observed. Phase changes are reversible and do not change the identity of the material. Mass stays constant during phase changes. **Grade 6 Concepts** Thermal energy can be thought of as the total amount of kinetic energy present in a substance or system through the random motion of its atoms and molecules. Thermal energy depends on the amount of the substance, whereas temperature does not depend on the amount of the substance. When two samples of the same material have the same mass, the sample having the higher temperature will have a greater thermal energy (e.g., a hot nickel has more thermal energy than a cold nickel). When two samples of the same material have the same temperature, the sample with the greater mass will have the greater thermal energy (e.g., a bucket of water has more thermal energy than a cup of water at the same temperature). Solids, liquids and gases vary in the motion, spacing and attractions between particles. Solid particles are close together and held more rigidly in a space by the attractions between the particles. However, solid particles can still vibrate back and forth within this space. Liquid particles may be slightly farther apart but move with more speed than solid particles. In liquids, particles can move from one side of the sample to another. Gas particles are much farther apart and move with greater speed than liquid or solid particles. Because of the large spaces between the particles, gases are easily compressed into smaller volumes by pushing the particles closer together. Most substances can exist as a solid, liquid or gas depending on temperature. Generally, for a specific temperature, materials that exist as solids have the greatest attraction between the particles. Substances that exist as gases generally have the weakest attraction between the particles. During phase changes, both the temperature and the mass of the substance remain constant. Particles (atoms and molecules) are not created or destroyed. There is simply a change in the motion of and spacing between the particles. Experiments and investigations (3-D and virtual) are used to demonstrate phase changes. Since moving atoms cannot be observed directly, provide the opportunity to experiment with temperature, phase changes and particle motion using virtual labs.

Future Application of Concepts
Grades 7-8: Mixtures and pure substances are investigated. Elements are classified as metals, nonmetals or metalloids based on their properties and position on the periodic table. Atoms can be joined together into separate molecules or large three-dimensional networks.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	States of matter		
	Develop and test a hypothesis about the behavior of three different states of matter in a closed retractable space (e.g., using a syringe, observe and record data when a solid, like a marshmallow, and a liquid is placed inside the chamber). Observe and graph the change in temperature during phase changes. Measure mass before and after a phase change. Discuss molecular position and motion in a substance as the phase change occurs.	Explain in terms of the atomic theory why gases can be easily compressed, while liquids and solids cannot. Explain how the arrangement of atoms determines the specific properties (e.g., compressibility, ability to take the shape of a container) of solids, liquids and gases.	Identify three states of matter. Describe the motion and arrangement of atoms for each state of matter Describe the changes in atoms' motion and position when substances undergo changes of state. Describe the relationship between temperature and thermal energy. Describe how mass affects thermal energy (e.g., compare the thermal energy of two samples of the same material with different masses which are at the same temperature).

Grade 6 continued

PHYSICAL SCIENCE (PS)

Topic: Matter and Motion

This topic focuses on the study of foundational concepts of the particulate nature of matter, linear motion, and kinetic and potential energy.

CONTENT STATEMENT	CONTENT ELABORATION
6.PS.3: There are two categories of energy: kinetic and potential. Objects and substances in motion have kinetic energy. Objects and substances can have energy as a result of their position (potential energy). **Note:** *Chemical and elastic potential energy should not be included at this grade; this is found in PS grade 7.*	**Prior Concepts Related to Energy** **PreK-2:** A variety of sounds and motions are experienced. The sun is the principal source of energy. Plants get energy from sunlight. **Grades 3-5:** Objects with energy have the ability to cause change. Thermal energy, electrical energy, light, sound and magnetic energy are forms of energy. Earth's renewable and nonrenewable resources can be used for energy. All processes that take place within organisms require energy. **Grade 6 Concepts** There are many forms of energy, but all can be put into two categories: kinetic and potential. Kinetic energy is associated with the motion of an object. The kinetic energy of an object changes when its speed changes. Potential energy is the energy of relative position between two interacting objects. Potential energy transforms to kinetic energy and vice versa as the distance between objects changes. Using the word "stored" to define potential energy is misleading. The word "stored" implies that the energy is kept by the object and not given away to another object. Therefore, kinetic energy also can be classified as "stored" energy. A rocket moving at constant speed through empty space has kinetic energy and is not transferring any of this energy to another object. Gravitational potential energy is associated with the height of an object above a reference position. The gravitational potential energy of an object changes as its height above the reference changes. Thermal energy can be thought of as the total amount of kinetic energy a substance has because of the random motion of its atoms and molecules. Sound energy is associated with the back and forth movement of the particles of the medium through which it travels. Opportunities to explore many types of energy should be provided. Virtual experiments that automatically quantify energy can be helpful since using measurements to calculate energy is above grade level. **Future Application of Concepts** **Grades 7-8:** Conservation of energy and methods of energy transfer, including waves, are introduced. Chemical and elastic potential energy are explored. **High School:** Standard formulas are used to calculate energy for different objects and systems.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Energy transfers in a device			
Design and build a system that uses moving water to cause a wheel to turn. Describe how this can be used to perform a task. Develop evaluation criteria and use them to compare the effectiveness of the waterwheels built by the class. Determine which design features are most effective and propose an explanation for why these features are effective. Redesign the water wheel to incorporate the best design practices.	Use the waterwheel to investigate the relationship between a variable (e.g., flow rate, volume of water) and the spin rate of the wheel.	Document the design process for the waterwheel including reasons for design decisions for each part, documentation of prototypes developed and the results of testing. Graphically represent the data collected from the investigation (e.g., water load, spin rate).	Classify the energy at each stage in the function of the waterwheel as kinetic, potential or a combination of the two. Explain the changes in energy that occur when the waterwheel is in operation.
Gravitational potential energy			
Design a roller coaster to demonstrate energy transformation between potential and kinetic.	Compare objects as they fall from various heights. Analyze the data to determine patterns and trends. Formulate a conclusion about the relationship between height and gravitational potential energy.	Outline and explain the energy changes involved in dropping an object onto the floor.	Recognize that increasing height increases gravitational potential energy. Recall that an object can have potential energy due to its position relative to another object and can have kinetic energy due to its motion.

Grade 6 continued

PHYSICAL SCIENCE (PS)

Topic: Matter and Motion

This topic focuses on the study of foundational concepts of the particulate nature of matter, linear motion, and kinetic and potential energy.

CONTENT STATEMENT

6.PS.4: An object's motion can be described by its speed and the direction in which it is moving.

An object's position and speed can be measured and graphed as a function of time.

Note: *Velocity and acceleration rates should not be included at this grade level; these terms are introduced in high school.*

CONTENT ELABORATION

Prior Concepts Related to Forces and Motion

PreK-2: Sound is produced by vibrating objects. Motion is a change in an object's position with respect to another object. Forces are pushes and pulls and are necessary to change the motion of an object. Greater changes of motion for an object require larger forces.

Grades 3-5: The amount of change in movement of an object is based on the mass of the object and the amount of force exerted. The speed of an object can be calculated from the distance traveled in a period of time.

Grade 6 Concepts

Speed can be calculated by dividing distance traveled by the elapsed time or can be found as the unit rate from a position versus time graph. This content aligns with mathematics standard 6.RP.3. When speed is calculated from a distance measurement, the distance is always measured from some reference point. To describe the motion of an object more thoroughly, the direction of motion can be indicated along with the speed.

Experiments and graph creation/interpretation can be used to investigate motion. Plotting time on the horizontal (x) axis and position on the vertical (y) axis creates a graph that can be used to compare and analyze motion. On position versus time graphs, fast motion is represented by steep lines, slow motion is represented by lines that are less steep, and no motion is represented by horizontal lines. The relative speeds and positions of different objects can be determined by comparing their position vs. time graphs. At this grade level, position vs. time graphs are used to interpret motion data, not as a set of rules to be memorized. Motion detectors can be used to compare the graphs resulting from different types of motion.

Note 2: *Using the word "vector" and exploring other aspects of vectors are not appropriate at this grade level. This content is a precursor to the introduction of vectors.*

Note 3: *At this grade level, interpretations of position vs. time graphs should be limited to comparing lines with different slopes to indicate whether objects are moving relatively fast, relatively slow or not moving at all. Calculation of slope is not appropriate at this grade level. More complex interpretations of position vs. time graphs will be made at higher grade levels.*

Future Application of Concepts

Grades 7-8: The concept of fields is introduced to describe forces at a distance. The concept of force is expanded to include magnitude and direction.

High School: Acceleration is introduced. Complex problems involving motion in two-dimensions and free fall will be solved. Complex position vs. time graphs, velocity vs. time graphs, and acceleration vs. time graphs will be analyzed conceptually and mathematically with connections made to the laws of motion.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Motion			
Given a mousetrap car and a recording method (e.g., motion detector), redesign the car so it will move to produce a steeper or less steep position vs. time graph.	Use data (e.g., from motion detectors) to produce distance vs. time graphs to investigate the effects of changes (e.g., steeper ramp, more batteries, harder push, heavier object) made to a moving object. Compare the graphs to determine relative speeds.	Graph an object's motion by measuring and recording its position over time. Use the unit rate of a position vs. time graph to determine the speed of an object moving at constant speed.	Given the distance traveled and the elapsed time, calculate the average speed of an object. Describe motion as the change over time in the position of an object compared to a reference point

Grade 6 continued

LIFE SCIENCE (LS)

Topic: Cellular to Multicellular
This topic focuses on the study of the basics of Modern Cell Theory. All organisms are composed of cells, which are the fundamental unit of life. Cells carry on the many processes that sustain life. All cells come from pre-existing cells.

CONTENT STATEMENT	CONTENT ELABORATION
6.LS.1: Cells are the fundamental unit of life. All living things are composed of cells. Different body tissues and organs are made of different kinds of cells. The ways cells function are similar in all living organisms. **Note:** *Emphasis should be placed on the function and coordination of cell organelles as well as their roles in overall cell function. Specific information about the organelles that need to be addressed at this grade level will be found in the model curriculum.*	**Prior Concepts Related to Cells** **PreK-2:** Living things have specific traits and are made up of a variety of structures. **Grades 3-5:** Organisms are made of parts. **Grade 6 Concepts** The content statements for sixth-grade life science are each partial components of a larger concept. The parts have been isolated to call attention to the depth of knowledge required to build to one of biology's foundational theories, Modern Cell Theory. It is recommended that the content statements be combined and taught as an integrated unit. For example, the energy needs of cells can be interwoven with the function of mitochondria. Modern Cell Theory states that all living things are made of cells. Cells are the basic unit of structure and function of all living things. Many organisms are single-celled and that one cell carries out all the basic functions of life. Other organisms are multicellular and the cells that form these organisms can be organized at various levels to carry out all the basic functions of life. Different body tissues and organs can be made up of different kinds of cells. The cells in similar tissues and organs in animals are similar. The tissues and organs found in plants differ slightly from similar tissues and organs in animals. Use Modern Cell Theory to exemplify how scientific theories are developed over time. The relationship between structure and function is a crosscutting theme for science and should be explored when investigating the structure and function of cellular organelles. Emphasis is placed on the function and coordination of these components, as well as on the overall cell function. Microscopes, micrographs, models and illustrations using appropriate safety procedures can be used to observe cells from many different types of organisms. The sizes and shapes of cells from single-celled organisms, fungi, plants and animals can be observed and compared. **Future Application of Concepts** **High School:** Details of cellular processes such as photosynthesis, chemosynthesis, cellular respiration, cell division and differentiation are studied.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		Cells	
Analyze and evaluate scientific tradeoffs for use of microbes to produce alternative energy or clean up environmental spills.		Explain how the cellular structures and their functions contribute to the survival of the cell. Consider models or authentic analogies to express understanding. Compare the organelles of a cell to a familiar working system (e.g. school, city, factory). Investigate different types of human cells (e.g., bone, muscle, skin, nerve, blood) using microscopes, models, micrographs, or illustrations. Compare types of cells by looking at different organelles and shapes. Compare cell structure to cell function.	Recognize that cells are the fundamental unit of life. Describe how the structure of specialized cells that form tissues (e.g., xylem, phloem, connective, muscle, nervous) relates to the function that the cells perform. Identify organelles within cells. Emphasis should be placed on those organelles involved in the following cellular functions: transport of materials, energy capture and release, protein building, waste disposal, information feedback and movement. Observe a variety of cells (using microscopes or online pictures/models). Label the visible cellular structures and explain how the structure is related to the function of the organelle in the cell.

Grade 6 continued

LIFE SCIENCE (LS)

Topic: Cellular to Multicellular
This topic focuses on the study of the basics of Modern Cell Theory. All organisms are composed of cells, which are the fundamental unit of life. Cells carry on the many processes that sustain life. All cells come from pre-existing cells.

CONTENT STATEMENT	CONTENT ELABORATION
6.LS.2: All cells come from pre-existing cells. Cells repeatedly divide resulting in more cells and growth and repair in multicellular organisms. **Note:** *This is not a detailed discussion of the phases of mitosis or meiosis. The focus should be on reproduction as a means of transmitting genetic information from one generation to the next, cellular growth and repair.*	**Prior Concepts Related to Species and Reproduction** **PreK-2:** Living things have specific traits and are made up of a variety of structures. **Grades 3-5:** Individual organisms inherit many traits from their parents indicating a reliable way to transfer information from one generation to the next. **Grade 6 Concepts** The content statements for sixth-grade life science are each partial components of a larger concept. The parts have been isolated to call attention to the depth of knowledge required to build to one of biology's important foundational theories: Modern Cell Theory. It is recommended that the content statements be combined and taught as an integrated unit. Modern Cell Theory states that cells come from pre-existing cells. Individual organisms do not live forever. Therefore, reproduction is necessary for the continuation of every species. Traits are passed on to the next generation through reproduction. Single-celled organisms reproduce by processes such as mitosis, budding and binary fission. In this grade, mitosis is explored. In multicellular organisms, mitosis allows cells to multiply for the purpose of growth and repair. All cells contain genetic materials. At this grade level, the genetic material is described as chromosomes. Chromosomes are described as structures in cells that contain genetic material. The chemicals and chemical processes associated with chromosomes are reserved for high school biology. Microscopes, micrographs, models and illustrations can be used to observe cells from different organisms in the process of dividing. It is not appropriate to learn the names of the stages of mitosis. The focus is on observing cells dividing as evidence that cells come from pre-existing cells and genetic material is transmitted from parent cell to daughter cells. The misconception of spontaneous generation can be included in discussions on this topic. The experiments of Redi and Pasteur can be used to explain how evidence can lead to new knowledge, better explanations and spur new technology. **Future Application of Concepts** **Grade 8:** More details about asexual and sexual reproduction will be studied.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Cell division			
	Do an observational study of the growth of an organism from zygote through embryogenesis in both plants and animals.	Model the movement of chromosomes during plant cell division and explain why this process ensures genetic information is passed from one generation to the next. Use the theory that all cells come from pre-existing cells to describe how human bones grow. Research body systems that are involved in human growth. Explain the role mitosis plays in human development (e.g., growth, repair, cancer).	Distinguish between the role of mitosis in single-celled organisms and multicellular organisms.

Grade 6 continued

LIFE SCIENCE (LS)

Topic: Cellular to Multicellular
This topic focuses on the study of the basics of Modern Cell Theory. All organisms are composed of cells, which are the fundamental unit of life. Cells carry on the many processes that sustain life. All cells come from pre-existing cells.

CONTENT STATEMENT	CONTENT ELABORATION
6.LS.3: Cells carry on specific functions that sustain life. Many basic functions of organisms occur in cells. Cells take in nutrients and energy to perform work, like making various molecules required by that cell or an organism. Every cell is covered by a membrane that controls what can enter and leave the cell. Within the cell are specialized parts for the transport of materials, energy capture and release, protein building, waste disposal, information feedback and movement. **Note:** *Emphasis should be placed on the function and coordination of cell components, as well as on their roles in overall cell function.*	**Prior Concepts Related to Cellular Functions** **PreK-2:** Living things have specific traits. Living things require energy, water and a particular temperature range. **Grades 3-5:** Organisms are made of structures. **Grade 6 Concepts** The content statements for sixth-grade life science are each partial components of a larger concept. The parts have been isolated to call attention to the depth of knowledge required to build to one of biology's important foundational theories: Modern Cell Theory. In classrooms, it is recommended that the content statements be combined and taught as an integrated unit (e.g., the energy requirements of cells can be interwoven with the function of mitochondria). Cells have particular structures that are related to their functions. These functions are regulated and controlled (e.g., a cell membrane controls what can enter and leave the cell). The organization of living systems includes an explanation of the role of cells, tissues, organs and organ systems that carry out life functions for organisms. Connections are to be made between cellular organelles and processes. These roles include maintaining homeostasis, gas exchange, energy transfers and transformation, transportation of molecules, disposal of wastes and synthesis of new molecules. Explore (3-D or virtually) conditions that optimize and/or minimize cellular function in a cell or an organism. Technology can also be used to run simulations to investigate specific outcomes and develop predictions about changes in functions. **Future Application of Concepts** **Grades 7-8:** Photosynthesis and respiration are compared. **High School:** Details of cellular processes are studied. Molecules enter and leave the cell by the mechanisms of diffusion, osmosis and active transport.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Cellular function			
Make bread to investigate yeast under different conditions (e.g., amount or type of sugar, amount or type of flour, temperature). Determine which set of conditions makes the bread least dense.	Conduct an investigation to determine the rate of respiration in yeast cells by varying sugar concentrations or other variables to determine the maximum release of carbon dioxide. **Note:** *Do not conduct a splint test for carbon dioxide.* Investigate osmosis as a way that cell membranes transport materials into/out of a cell. Relate findings to how drugs and other chemicals enter human cells.	Compare various cell types (e.g., muscle, skin, root, stem, leaf) in plants and animals paying close attention to function and structure. Develop models to demonstrate how the various cells of the human immune system function to protect the human body from disease. Explain how different types of blood cells carry out specific functions in the human body. Research technology that is being used to replicate human tissues.	Describe the function of a given cell part. Describe how different organ systems interact to enable complex multicellular organisms to survive.

Grade 6 continued

LIFE SCIENCE (LS)

Topic: Cellular to Multicellular
This topic focuses on the study of the basics of Modern Cell Theory. All organisms are composed of cells, which are the fundamental unit of life. Cells carry on the many processes that sustain life. All cells come from pre-existing cells.

CONTENT STATEMENT

6.LS.4: Living systems at all levels of organization demonstrate the complementary nature of structure and function.

The level of organization within organisms includes cells, tissues, organs, organ systems and whole organisms.

Whether the organism is single-celled or multicellular, all of its parts function as a whole to perform the tasks necessary for the survival of the organism.

Organisms have diverse body plans, symmetry and internal structures that contribute to their being able to survive in their environments.

CONTENT ELABORATION

Prior Concepts Related to Structure and Function of Living Things
PreK-2: Living things have specific traits. Living things require energy, water and a particular temperature range.

Grades 3-5: Organisms are made of structures.

Grade 6 Concepts
The content statements for sixth-grade life science are each partial components of a larger concept. The parts have been isolated to call attention to the depth of knowledge required to build to one of biology's important foundational theories: Modern Cell Theory. It is recommended that the content statements be taught as an integrated unit (e.g., levels of organization can be interwoven with the concept of cells as the fundamental unit of life).

Cells perform specialized functions in multicellular organisms. Groups of specialized cells form a tissue such as muscle. Different tissues are, in turn, grouped together to form larger functional units, called organs. Each type of cell, tissue and organ has a distinct structure and set of functions that serve the organism.

Organisms have diverse body plans, symmetry and internal structures. General distinctions among organisms (e.g., internal structures, body systems, body plans, and symmetry) that support classifying them into a scientifically based system (a distinction of this grade level from Pre-K to 5) are explored. Organisms sorted into groups share similarities in external structures, internal structures and processes.

The commonality of life can be investigated through observing tissues, organs, cell structures, systems and symmetry (an approximate balanced distribution of duplicate body parts) for plants and animals. Part of the exploration of the commonality of living systems can include a comparison of cells, types of tissues, organs and organ systems between organisms. View a variety of cells, tissues (e.g., xylem, phloem, connective, muscle, nervous) and organs (e.g., leaf, stem, flower, spore, ganglia, blood vessels, eyes) to compare their similarities and differences. Real-world applications (e.g., the presence of microbes in potable water), new technology and contemporary science can be explored. Inquiry and mathematical relationships should be drawn between cell size and the cell's ability to transport necessary materials into its interior. This link is critical for laying the foundation for the cell cycle in grade 8.

Note: *Living organisms are often organized in classification systems to assist in studying their similarities and differences. These classification systems change as new information emerges. The focus should not be on naming kingdoms rather on comparing internal structures, body systems, body plans and symmetry. Students should focus on how classification is useful as a tool rather than memorizing any particular system.*

Future Application of Concepts
Grade 8: Cellular reproduction is studied.

High School: The unity and diversity of life and the evolutionary mechanisms that contribute to the organization of living things are studied.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Levels of organization			
	Conduct a study to compare organisms that are living in an aquatic environment to those living in a terrestrial environment. Hypothesize how the structure can put limits on the size and shape of the organisms in each environment.	Compare a variety of plant and animal cells, tissues (e.g., xylem, phloem, connective, muscle, nervous) and organs (e.g., leaf, stem, flower, spore, ganglia, blood vessels, eyes). Given a particular environment, describe specific internal structures, body plan, and symmetry an organism would need for survival. Create a model or system that shows the progression of the levels of organization from cell to organism in a human. Compare the four major types of tissues (epithelial, connective, nerve and muscle).	Identify general distinctions among the cells of organisms that support classifying some as plants, some as animals and some that do not neatly fit into either group (e.g. fungi, bacteria). Given a group of organisms, classify them based on internal structures, body system and symmetry. Provide justification for the classifications.

Grade 7

INTRODUCTION TO CONTENT STATEMENTS

GRADE BAND THEME: ORDER AND ORGANIZATION

This theme focuses on helping students use scientific inquiry to discover patterns, trends, structures and relationships that may be inferred from simple principles. These principles are related to the properties or interactions within and between systems.

STRANDS

Strand Connections: Systems can exchange energy and/or matter when interactions occur within systems and between systems. Systems cycle matter and energy in observable and predictable patterns.

EARTH AND SPACE SCIENCE (ESS)	PHYSICAL SCIENCE (PS)	LIFE SCIENCE (LS)
Topic: Cycles and Patterns of Earth and the Moon This topic focuses on Earth's hydrologic cycle, patterns that exist in atmospheric and oceanic currents, the relationship between thermal energy and the currents, and the relative position and movement of the Earth, sun and moon.	**Topic: Conservation of Mass and Energy** This topic focuses on the empirical evidence for the arrangements of atoms on the Periodic Table of Elements, conservation of mass and energy, transformation and transfer of energy.	**Topic: Cycles of Matter and Flow of Energy** This topic focuses on the impact of matter and energy transfer within the biotic component of ecosystems.
CONDENSED CONTENT STATEMENTS		
7.ESS.1 The hydrologic cycle illustrates the changing states of water as it moves through the lithosphere, biosphere, hydrosphere and atmosphere. **7.ESS.2** Thermal-energy transfers in the ocean and the atmosphere contribute to the formation of currents, which influence global climate patterns. **7.ESS.3** The atmosphere has different properties at different elevations and contains a mixture of gases that cycle through the lithosphere, biosphere, hydrosphere and atmosphere. **7.ESS.4** The relative patterns of motion and positions of Earth, moon and sun cause solar and lunar eclipses, tides and phases of the moon. **7.ESS.5** The relative positions of Earth and the sun cause patterns we call seasons.	**7.PS.1** Elements can be organized by properties. **7.PS.2** Matter can be separated or changed, but in a closed system, the number and types of atoms remains constant. **7.PS.3** Energy can be transformed or transferred but is never lost. **7.PS.4** Energy can be transferred through a variety of ways.	**7.LS.1** Energy flows and matter is transferred continuously from one organism to another and between organisms and their physical environments. **7.LS.2** In any particular biome, the number, growth and survival of organisms and populations depend on biotic and abiotic factors.

NATURE OF SCIENCE GRADES 6-8

Nature of Science
One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.

Categories	6-8
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Apply knowledge of science content to real-world challenges. • Identify questions that can be answered through scientific investigations. • Design and conduct scientific investigations using appropriate safety techniques. • Use appropriate mathematics, tools and techniques to gather data and information. • Analyze and interpret data. • Develop descriptions, models, explanations and predictions. • Think critically and logically to connect evidence and explanations. • Recognize and analyze alternative explanations and predictions. • Communicate scientific procedures and explanations. • Design technological/engineering solutions.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	• Science is a way of knowing about the world around us based on evidence from experimentation and observations. • Science is a continual process and the body of scientific knowledge continues to grow and change. • Science assumes that objects and events occur in consistent patterns that are understandable through measurement and observation. • Science should carefully consider and evaluate all data including outliers. • Science is based on observable phenomena and empirical evidence. • Science disciplines share common rules for obtaining and evaluating empirical evidence.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• Individuals from different social, cultural, and ethnic backgrounds work as scientists and engineers. • Scientists and engineers are guided by habits of mind, such as intellectual honesty, tolerance of ambiguity, skepticism and openness to ideas. • Scientists and engineers rely on human qualities such as persistence, precision, reasoning, logic, imagination and creativity.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• Science explanations are subject to revision and improvement in light of additional scientific evidence or new understanding of scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Complete *Nature of Science* document is found on pages 8-12.

Grade 7 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Cycles and Patterns of Earth and the Moon
This topic focuses on Earth's hydrologic cycle, patterns that exist in atmospheric and oceanic currents, the relationship between thermal energy and the currents, and the relative position and movement of the Earth, sun and moon.

CONTENT STATEMENT

7.ESS.1: The hydrologic cycle illustrates the changing states of water as it moves through the lithosphere, biosphere, hydrosphere and atmosphere.

Thermal energy is transferred as water changes state throughout the cycle. The cycling of water in the atmosphere is an important part of weather patterns on Earth. The rate at which water flows through soil and rock is dependent upon the porosity and permeability of the soil or rock.

CONTENT ELABORATION

Prior Concepts Related to Hydrologic Cycle
PreK-2: Water is observed through weather. Water is in the atmosphere. Water can be a solid, a gas and a liquid.

Grades 3-5: Water is present in soil. Water is a non-living resource. Properties of the different states of water, how water can change the surface of Earth and how water is a factor in some weather-related events (e.g., flooding, droughts) are discussed.

Grade 6: The changes in the state of water are related to the motion of atoms (changes in energy). Water flows through rock and soil (porosity and permeability).

Grade 7 Concepts
The different aspects of the hydrologic cycle (e.g., properties of water, changes of state, relationships of water to weather, effects of water on Earth's surface) from the elementary grades are formally combined in grade 7 and applied to the components of the hydrologic cycle.

The movement of water through the spheres of Earth is known as the hydrologic cycle. As water changes state and energy is transferred, it cycles from one sphere into another (e.g., water transfers from the hydrosphere to the atmosphere when evaporation occurs). Groundwater and surface water quality are components of the hydrologic cycle. The porosity and permeability of the rock and/or soil can affect the rate at which the water flows. The pattern of the cycling illustrates the relationship between water, energy and weather.

The movement of water in the cycle can have both positive and negative impacts, such as nutrient and contaminant transport. Contamination can occur within any step of the hydrologic cycle. Groundwater is easily contaminated as pollution present in the soil or spilled on the ground surface moves into the groundwater and impacts numerous water sources. Relating water flow to geographic and topographic landforms and/or features leads to an understanding of where water flows and how it moves through the different spheres. Topographic and aerial maps (can be virtual) can be used to identify drainage patterns and watersheds that contribute to the cycling of water. Lab investigations or technology can be used to simulate different segments of the hydrologic cycle.

Future Application of Concepts
Grade 8: The relationship between the hydrosphere, atmosphere and lithosphere are studied as they relate to weathering and erosion.

High School: The hydrologic cycle is a component of biology as it relates to ecosystems and the diversity of life. In Environmental Science, the connections and interactions of energy and matter between Earth's spheres are researched and investigated in more depth

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	Hydrologic cycle		
Design and test solutions for reducing acid rain, road salt runoff, erosion and/or surface runoff rates in specific regions (e.g., urban, agricultural, construction). Present findings/plan to school administrators or local government. Develop, test and evaluate plans outlining methods to reduce storm water flow at a site in the local community (e.g., a housing construction project, the school parking lot). Present findings/plans to school administrators or local government.	Design and conduct an investigation to measure and analyze surface-water discharge rates. Build a model to represent a cross section of Earth's surface (e.g., topography, soil, rock, groundwater) that can enable investigation of multiple water pathways. Investigate and use different methods and tools that measure water flow and water quality, and evaluate which methods and tools are most effective for the desired outcome.	Use GPS/GIS programs, geographic, topographic and/or aerial maps to identify water flow and drainage patterns. Identify regions where surface water run-off and/or acid rain could impact ground or surface water quality. Investigate an area in Ohio that exhibits a water contamination problem (e.g., acid mine drainage in southeastern Ohio, mercury contamination and algae blooms in Lake Erie). Document recent discoveries, case studies, cleanup technologies or field investigations that are occurring in these areas.	Describe the movement of water through all four spheres of Earth (lithosphere, hydrosphere, atmosphere, biosphere). Identify the changes in thermal energy as water changes state in the hydrologic cycle. Explain the roles of the sun and gravity in the hydrologic cycle.

Grade 7 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Cycles and Patterns of Earth and the Moon
This topic focuses on Earth's hydrologic cycle, patterns that exist in atmospheric and oceanic currents, the relationship between thermal energy and the currents, and the relative position and movement of the Earth, sun and moon.

CONTENT STATEMENT	CONTENT ELABORATION
7.ESS.2: Thermal-energy transfers in the ocean and the atmosphere contribute to the formation of currents, which influence global climate patterns. The sun is the major source of energy for wind, air and ocean currents and the hydrologic cycle. As thermal energy transfers occur in the atmosphere and ocean, currents form. Large bodies of water can influence weather and climate. The jet stream is an example of an atmospheric current and the Gulf Stream is an example of an oceanic current. Ocean currents are influenced by factors other than thermal energy, such as water density, mineral content (such as salinity), ocean floor topography and Earth's rotation. All of these factors delineate global climate patterns on Earth.	**Prior Concepts Related to Energy Transfers, Atmosphere and Hydrosphere** **PreK-2**: Water is observed through weather. Water is in the atmosphere. Water can be a solid, a gas and a liquid. **Grades 3-5:** Water is present in soil. Water is a non-living resource. Properties of the different states of water, how water can change the surface of Earth and how water is a factor in some weather-related events (e.g., flooding, droughts) are discussed. **Grade 6:** The changes in the state of water are related to the motion of atoms. Atoms take up space and have mass. Changes of state occur due to the amount of motion of atoms and molecules. Density is a property of matter. **Grade 7 Concepts** The earlier concepts of weather and the physical properties of air and water, and their changes are expanded in grade 7 to the relationship of atmospheric and oceanic currents and climate. Current and climate patterns on a global level should be studied using a variety of maps, models and technology (e.g., remote sensing, satellite images, LANDSAT). The causes of moving currents in the atmosphere and ocean are connected to thermal energy, density, pressure, composition and topographic/geographic influences (e.g., continental mountains, ocean ridges). Studies should also include specific current patterns in both the atmosphere and the ocean that are mapped and documented through data. Contemporary studies regarding global climate must be based on facts and evidence. This content statement is connected to the Life Science, grade 7 content pertaining to biomes and the climatic zones of Earth. **Future Application of Concepts** **Grade 8:** In grade 8, global climate is expanded through the investigation of climate change that occurred throughout Earth's history (as evidenced through the rock record and more recently though ice cores). **High School:** Gravity, density, gases and properties of air and water are found in physical science courses. In the Physical Geology and Environmental Science courses, climate change is explored in greater depth.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Ocean and atmospheric currents			
Using the analytical data from Demonstrating Science Knowledge, evaluate and map the fastest and most effective route to travel from Spain to Florida. Document all scientific data, data analysis and steps in the evaluation process to support the selection.	Using Adopt a Buoy data (NOAA), calculate the average buoy velocities at specific segments of the year. Predict where ocean current patterns change and may result in climate changes (based on the data). How does this relate to Jet Stream patterns and changes? Present findings to the class and be prepared to defend the predictions using evidence and data.	Analyze data from storms (e.g. hurricane debris in the Atlantic Ocean) to map currents. Analyze data from debris and materials falling off ships in the Pacific to track and map currents in the ocean. Record drifter-buoy velocity data in a graph or chart. Use the velocity data to make a simple map showing the general patterns of the Gulf Stream. Research the documented patterns of the Jet Stream.	Identify the general patterns of the Jet Stream and the Gulf Stream using a world map.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Drifter buoys			
Drifter buoys are ocean buoys that are equipped with sensors that can transmit data (e.g., water temperature, air temperature, location) via satellites. Based on the interpretation and analysis of drifter buoy data, develop a list of criteria (including cost) for successful buoy deployment and life span. Design, build and test a buoy that can sample water temperatures or another water-quality test (e.g., pH, turbidity levels) of a local lake, pond, pool or stream. Deploy the buoy and collect/analyze data. Compare and discuss results with the class.	Analyze real-time drifter buoy data to determine the pattern of the Gulf Stream. Compare the present pattern with documented seasonal patterns over a five-year period. Using quantifiable data, outline factors that contribute to the changing patterns and influence the Gulf Stream. Additional buoy data is available at NOAA Drifter Buoy Program.	Adopt a drifter buoy (NOAA), record its movement and record water temperature data over time. Represent the oceanic data on a graph or chart.	Identify the factors that contribute to global climate.

Grade 7 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Cycles and Patterns of Earth and the Moon
This topic focuses on Earth's hydrologic cycle, patterns that exist in atmospheric and oceanic currents, the relationship between thermal energy and the currents, and the relative position and movement of the Earth, sun and moon.

CONTENT STATEMENT

7.ESS.3: The atmosphere has different properties at different elevations and contains a mixture of gases that cycle through the lithosphere, biosphere, hydrosphere and atmosphere.

The atmosphere is held to the Earth by the force of gravity. There are defined layers of the atmosphere that have specific properties, such as temperature, chemical composition and physical characteristics. Gases in the atmosphere include nitrogen, oxygen, water vapor, carbon dioxide and other trace gases. Biogeochemical cycles illustrate the movement of specific elements or molecules (such as carbon or nitrogen) through the lithosphere, biosphere, hydrosphere and atmosphere.

Note: *The emphasis is on why the atmosphere has defined layers, not on naming the layers.*

CONTENT ELABORATION

Prior Concepts Related to Atmosphere
PreK-2: Wind is air in motion. Wind speed and direction can be measured. Sunlight warms the air. The atmosphere is primarily made up of air. Air has properties. Transfer of energy causes air movement. Water is present in the atmosphere.

Grades 3-5: Air is a non-living resource that can be used for energy. Air can be contaminated. Wind can change the surface of Earth. Earth is a planet that has an atmosphere.

Grade 6: Atoms take up space, have mass and are in constant motion. Elements and molecules are discussed. Changes of state occur due to the amount of motion of atoms and molecules.

Grade 7 Concepts
The properties and composition of the layers of Earth's atmosphere are studied, as they are essential in understanding atmospheric currents, climate and biogeochemical cycles, which are seventh-grade concepts.

Understanding the interactions between Earth's spheres (Earth Systems Science) and how specific elements and/or compounds move between them should be emphasized. This study includes standard greenhouse gases (including water vapor), ozone (in the atmosphere and at Earth's surface) and natural events/human activities that can change the properties of the atmosphere. Contemporary issues and technological advances should be included within this concept. Real-time scientific data pertaining to air quality and properties of air can be incorporated into the study of atmospheric properties and air quality.

Future Application of Concepts
Grade 8: Changes in environmental and climate conditions (including atmospheric changes) as evidenced in the rock record and contemporary studies of ice cores are studied.

High School: Gravity, density, gases and properties of air are found in physical science courses. In Physical Geology and Environmental Science, the atmosphere and climate change are explored further.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Atmosphere			
Build a model of a human lung and use it to explore the impact of air pollution on lung tissue.	Plan and implement an investigation to collect and test ground levels of ozone or carbon monoxide in a local area. Compare results to statewide data. Determine the existing factors that contribute to these levels. Use data sets to investigate the relationship between air pressure, elevation and temperature.	Using ozone data from the stratospheric level, generate a graph that illustrates the changes in the ozone over a specific period of years. Explain how humans are a part of the biogeochemical cycles through gas exchanges in the respiratory system. Research how humans obtain and process nitrogen. Include the role of nitrogen-fixing microbes, uptake by plants, processing by the liver and elimination through the urinary system.	Identify the general properties of the different layers of the atmosphere. Recognize human-made and natural factors that can change the properties of the atmosphere. Identify the different gases that are present in Earth's atmosphere. Trace the different biogeochemical cycles through each of Earth's spheres.

Grade 7 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Cycles and Patterns of Earth and the Moon

This topic focuses on Earth's hydrologic cycle, patterns that exist in atmospheric and oceanic currents, the relationship between thermal energy and the currents, and the relative position and movement of the Earth, sun and moon.

CONTENT STATEMENT

7.ESS.4: The relative patterns of motion and positions of Earth, moon and sun cause solar and lunar eclipses, tides and phases of the moon.

The moon's orbit and its change of position relative to Earth and sun result in different parts of the moon being visible from Earth (phases of the moon).

A solar eclipse is when Earth moves into the shadow of the moon (during a new moon). A lunar eclipse is when the moon moves into the shadow of Earth (during a full moon).

Gravitational force between Earth and the moon causes daily oceanic tides. When the gravitational forces from the sun and moon align (at new and full moons) spring tides occur. When the gravitational forces of the sun and moon are perpendicular (at first and last quarter moons), neap tides occur.

CONTENT ELABORATION

Prior Concepts Related to Moon, Earth and Sun

PreK-2: The moon, sun and stars can be observed at different times of the day or night. The observable shape of the moon changes throughout the month. The sun's position appears to change in a single day and from day to day. The sun is the principal source of energy.

Grades 3-5: Earth's atmosphere, introduction to gravitational forces, orbits of planets and moons within the solar system and predictable cycles and patterns of motion between Earth and the sun are explored.

Grade 6: Objects and substances in motion have kinetic energy. Objects and substances can store energy as a result of their positions (gravitational potential energy).

Grade 7 Concepts

The role of gravitational forces and tides are introduced with relation to the position of Earth, moon and sun. Models and simulations (can be 3-D or virtual) are used to demonstrate the changing positions of the moon and Earth (as they orbit the sun) and lunar/solar eclipses, daily tides, neap and spring tides and the phases of the moon. Our solar system is a part of the Milky Way galaxy, which is part of the universe.

The emphasis should not be on naming the phases of the moon or tides, but in understanding why the phases of the moon or tides are cyclical and predictable. Advances in scientific knowledge regarding patterns and movement in the solar system are included in this content statement.

Future Application of Concepts

Grade 8: Gravitational forces, frame of reference, and net forces affecting motion are studied in more detail.

High School: Patterns of motion within the solar system are expanded to the universe. The Big Bang theory and origin of the universe are explored. Forces and motion are investigated in depth.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Patterns of motion and positions of Earth, moon and sun			
Make a recommendation for a site to build a tidal power plant in the United States. Research the coastal conditions (e.g., ocean depth, geographic features, currents) necessary for tidal power facilities. Support your site selection with tidal and coastline data.	Investigate the factors that must exist for a full or partial solar or lunar eclipse using 3-D modeling.	Make a chart or graph that illustrates moon phases, Earth's rotation, sun position and resulting tidal data for one month. Include specific data about spring and neap tides. Use actual data to document the graphic representation.	Describe the relationship between gravity and tidal movement. Map the different phases of the moon during a cycle.

Grade 7 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Cycles and Patterns of Earth and the Moon
This topic focuses on Earth's hydrologic cycle, patterns that exist in atmospheric and oceanic currents, the relationship between thermal energy and the currents, and the relative position and movement of the Earth, sun and moon.

CONTENT STATEMENT

7.ESS.5: The relative positions of Earth and the sun cause patterns we call seasons.

Earth's axis is tilted at an angle of 23.5°. This tilt along with Earth's revolution around the sun, affects the amount of direct sunlight that the earth receives in a single day and throughout the year. The average daily temperature is related to the amount of direct sunlight received.

CONTENT ELABORATION

Prior Concepts Related to Moon, Earth and Sun
PreK-2: The moon, sun and stars can be observed at different times of the day or night. The observable shape of the moon changes throughout the month. The sun's position appears to change in a single day and from day to day. The sun is the principal source of energy.

Grades 3-5: Earth's atmosphere, introduction to gravitational forces, orbits of planets and moons within the solar system and predictable cycles and patterns of motion between Earth and sun are explored.

Grade 6: Objects and substances in motion have kinetic energy. Objects and substances can store energy as a result of their positions (gravitational potential energy).

Grade 7 Concepts
Each day, the total energy that a particular location on Earth receives from sunlight is directly related to the angle at which the sun's rays strike Earth and the amount of time the sun is above the horizon (i.e. the number of hours of sunlight). Seasonal change should be expanded to include regions of the world that experience specific seasonal weather patterns and natural weather hazards (e.g., hurricane season, monsoon season, rainy season, dry season). This builds upon making observations of the seasons throughout the school year in the earlier grades.

Three-dimensional models are used to demonstrate that the tilt of Earth's axis is related to the amount of direct sunlight received and seasonal temperature changes.

Future Application of Concepts
High School: Patterns of motion within the solar system are expanded to the universe. The Big Bang theory and origin of the universe are explored. Forces and motion are investigated in depth.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Causes of seasons			
Solar energy collection is most effective in areas that receive the most direct sunlight for long periods of time. Research the amount of sunlight received in specific locations around Ohio. Evaluate the data and make a recommendation for a location to build a solar-powered electric generation facility. Defend your proposed location. Compare the effectiveness of solar power in Ohio with other areas of the United States.		Use data for the amount of sunlight that different regions (e.g., Ohio, polar regions, tropics, northern vs. southern hemisphere) on Earth receive in a single day, to identify and compare patterns over a period of time. Explain weather and seasons based on the amount and intensity of sunlight. This can be tied to 7.ESS.2. Create a physical model (including an axis tilted 23.5°) to demonstrate how the angle of sunlight striking Earth's surface causes seasons and varies for different locations at different points in Earth's orbit.	Demonstrate that Earth's spin axis is fixed and tilted at 23.5° relative to its orbit around the sun. Explain that the rotation of Earth on its tilted axis, in conjunction with its revolution around the sun, affects the amount of direct sunlight that each portion of Earth receives in a single day and throughout the year. Explain that seasons are a result of Earth's tilted axis and are caused by the differential intensity of sunlight on different areas of Earth throughout the year.

Grade 7 continued

PHYSICAL SCIENCE (PS)

Topic: Conservation of Mass and Energy
This topic focuses on the empirical evidence for the arrangements of atoms on the Periodic Table of Elements, conservation of mass and energy, transformation and transfer of energy.

CONTENT STATEMENT	CONTENT ELABORATION
7.PS.1: Elements can be organized by properties. Elements can be classified as metals, non-metals and metalloids, and can be organized by similar properties such as color, solubility, hardness, density, conductivity, melting point and boiling point, viscosity, and malleability. **Note 1:** *This is the conceptual introduction of the Periodic Table of Elements and should be limited to classifications based on observable properties; it should not include the names of the families.*	**Prior Concepts Related to Properties of Matter** **PreK-2:** Properties can be used to sort objects. Changes, including phase changes, are explored. **Grades 3-5:** Objects are composed of matter which has mass and volume. Properties of solids, liquids and gases are explored. Phase changes are reversible and do not change the identity of the material. The total amount of matter and mass remains the same when something changes. **Grade 6:** All matter is made up of atoms that are in constant random motion. Elements are introduced. The properties of solids, liquids and gases and changes of phase are explained by the motion and spacing of the particles. **Grade 7 Concepts** All substances are composed of one or more elements. Elements are organized into groups based on their properties (including melting and/or boiling points). Elements with similar properties are grouped together on the periodic table. These groups include metals, non-metals and metalloids. Most metals are malleable, have high melting points, are usually solid at room temperature and are good conductors of heat and electricity. Nonmetals are poor conductors of heat and electricity and tend to be dull and brittle in the solid state. Depending on the element, they may be solid, liquid or gas at room temperature. Metalloids demonstrate some properties of both metals and non-metals. **Future Application of Concepts** **High School:** Acids, bases and pH are introduced. Mixtures are classified as homogeneous or heterogeneous. Trends in the properties and atomic structure of elements are related to the periodic table. The role of valence electrons in reactivity is explored, and stoichiometric problems are solved.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		Properties of elements	
Select elements that would be appropriate for use in certain products (e.g., a pan, an electronic device, a cooler) based on the intended usage of the product and the properties of the element.		Research element facts (e.g., melting point, boiling point, brittle vs. malleable, electrical conductivity, luster). Create a classification system and provide a rationale for the system.	Explain that the periodic table is organized based on physical and chemical properties. Identify characteristics of metals, non-metals and metalloids. Given a set of elements identify similar properties (e.g., melting and/or boiling points, conductors of heat and electricity, luster, brittle) and classify these elements as metals, nonmetals and metalloids.

Grade 7 continued

PHYSICAL SCIENCE (PS)

Topic: Conservation of Mass and Energy
This topic focuses on the empirical evidence for the arrangements of atoms on the Periodic Table of Elements, conservation of mass and energy, transformation and transfer of energy.

CONTENT STATEMENT

7.PS.2: Matter can be separated or changed, but in a closed system, the number and types of atoms remains constant.

When substances interact and form new substances the properties of the new substances may be very different from those of the original substances, but the amount of mass does not change.

Physically combining two or more substances forms a mixture, which can be separated through physical processes.

Note: *Under these standards, classifying specific changes as chemical or physical is not appropriate*.

CONTENT ELABORATION

Prior Concepts Related to Properties of Matter
PreK-2: Properties can be used to sort objects. Changes, including phase changes, are explored.

Grades 3-5: Objects are composed of matter which has mass and volume. Properties of solids, liquids and gases are explored. Phase changes are reversible and do not change the identity of the material. The total amount of matter and mass remains the same when something changes.

Grade 6: All matter is made up of atoms that are in constant random motion. Elements are introduced. The properties of solids, liquids and gases and changes of phase are explained by the motion and spacing of the particles.

Grade 7 Concepts
Elements are basic building blocks of matter that are uniform and not further broken into simpler substances by chemical or physical means. Instruction on subatomic particles is reserved for high school.

Compounds are composed of two or more different elements joined together chemically. Each compound has its own unique composition of type and number of elements and atoms.

Molecules are the combination of two or more atoms that are joined together chemically. Molecules can be either elements or compounds (e.g., elemental hydrogen is a molecule containing two atoms of hydrogen; water is a molecule containing two atoms of hydrogen joined with one atom of oxygen).

All particles of a pure substance have nearly identical mass. Particles of different substances usually have different masses, depending on their composition. Each element and compound has properties, some of which are independent of the amount of the sample.

For any change in a closed system, the number and type of atoms stay the same, even if the atoms are rearranged. Therefore, the mass remains constant. Mass is always conserved in a closed system; this is not always the case for volume. Mixing isopropyl alcohol (90%) with water results in a volume that is less than the sum of the volumes. Heating liquid results in an increase in volume. The conservation of matter can be demonstrated using simple balanced equations with their chemical formulas or pictorial representations of the reactants and products. The equations for photosynthesis and cellular respiration can be used to demonstrate this concept.

Energy input is required to break a molecule apart. When the separated atoms form new molecules, the output energy can be greater than or less than the original input energy.

Mixtures are materials composed of two or more substances that retain their separate compositions, even when mixed (e.g., water and sugar can be mixed together thoroughly at the molecular level but the water particles and sugar particles remain separate). When a solid substance dissolves in water, the particles of the solid separate and move freely with the water particles. Types of mixtures include solutions, suspensions, and colloids.

Future Application of Concepts
High School: Mixtures are classified as homogeneous or heterogeneous. The role of valence electrons in reactivity is explored, more complex balanced chemical equations are written and stoichiometric problems are solved.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Matter			
	Analyze an unknown mixture then create and implement a plan to separate the mixture using physical processes.	Explain why mass is always conserved in a closed system, but volume is not (e.g., mixing isopropyl alcohol with water, pouring sand into gravel, heating a substance). Use a simple balanced chemical equation to explain the Law of Conservation of Mass.	Compare the properties of different elements and the compounds formed from them (e.g., hydrogen and oxygen vs. water, chlorine and sodium vs. salt). Identify properties of compounds, molecules and mixtures. Display a simple balanced equation using pictorial representations of reactants and products. Define open and closed systems. Identify and provide examples of types of mixtures (e.g., solutions, suspensions, colloids).

Grade 7 continued

PHYSICAL SCIENCE (PS)

Topic: Conservation of Mass and Energy
This topic focuses on the empirical evidence for the arrangements of atoms on the Periodic Table of Elements, conservation of mass and energy, transformation and transfer of energy.

CONTENT STATEMENT	CONTENT ELABORATION
7.PS.3: Energy can be transformed or transferred but is never lost. When energy is transferred from one system to another, the quantity of energy before transfer equals the quantity of energy after transfer. When energy is transformed from one form to another, the total amount of energy remains the same.	**Prior Concepts Related to Energy Transfer** **PreK-2:** Sound is produced by vibrating objects. The sun is the principal source of energy and affects the warming or cooling of Earth. Weather changes occur due to changes in energy. Plants get energy from sunlight and animals get energy from plants and other animals. **Grades 3-5:** Objects with energy have the ability to cause change. Energy can transfer from one location or object to another and can be transformed from one form to another (e.g., light, sound, heat, electrical energy, magnetic energy). Earth's resources can be used for energy. Sunlight is transformed by producers into energy that organisms can use and pass from organism to organism. **Grade 6:** There are two forms of energy: kinetic and potential. Energy can transform from one form to another. Thermal energy is due to the random motion of the particles of a substance. **Grade 7 Concepts** A system is separated from its surroundings by either a physical or mental boundary. An isolated system is one that does not interact with its surroundings. Matter and energy cannot get into or out of an isolated system. Most systems on Earth are open systems. Matter and energy can be transferred into or out of an open system. If energy appears to be gained or lost, it has just transformed or transferred into a different system. Examples of systems include ecosystems, the atmosphere, the hydrosphere, the solar system and the human body. When energy transfers to a large system, it may be difficult to measure the effects of the added energy. Dissipated energy (energy that is transformed into thermal energy and released into the surroundings) is difficult or impossible to recapture. Some systems dissipate less energy than others, leaving more energy to use. Investigation, testing and experimentation are used to explore energy transfers and transformations. Observing the quantifiable energy changes in a virtual environment is recommended at this introductory level, as energy changes can be difficult to measure accurately. **Future Application of Concepts** **High School:** Waves are further explored as a method of transferring energy. Basic formulas are used to perform calculations with energy. Work is a method of, and power is a rate of, energy transfer.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Energy transformations			
Design and build a solar oven. Trace the energy transformations that are occurring.	Plan and implement a scientific experiment to explore energy transformations for a skateboarder using the Skate Park simulation. The program can track changes in different types of energy over time. Analyze the data to determine patterns and trends. Formulate a conclusion about energy transformations. Share the results with the class.	Given a project or situation (e.g., playing football, a solar-powered calculator) trace the energy transformations through the system, beginning with the Sun's energy and culminating with an observable phenomenon on Earth (e.g., throwing a ball, displaying numbers).	
Conservation of energy within a system			
Use everyday materials to design and construct a machine that performs a simple task in many steps. Test the machine as each additional component is added. Redesign to solve problems encountered during the testing and to reduce the loss of energy to the surrounding environment. Record any problems encountered as well as the changes made to the machine to overcome these problems.	Use design software to make a labeled pictorial representation of the final project design (from Designing technological/engineering solutions). Explain the solutions to problems encountered during testing.	Trace all the energy transformations that occur as a machine performs its task. Explain why the energy from a teaspoon of hot water appears to have disappeared as it is placed into a gallon of room temperature water. Explain where the energy of a swinging pendulum goes as it slows to an eventual stop.	Identify where energy has been dissipated to the environment. Describe two ways that energy can leave a system so it may appear to disappear. Recognize that energy or matter cannot enter or leave a closed system.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Roller coaster energy transformations			
Design and construct a roller coaster so that a marble will travel over a track that involves at least three hills. Apply the Law of Conservation of Energy to the roller coaster design.		Make a series of bar graphs that show kinetic energy, potential energy and thermal energy for eight different positions on a roller coaster. Place each set of bar graphs on a different index card for each position and shuffle the cards. Switch index cards and roller coaster designs with another group in the class. Organize the index cards in the correct order for the coaster.	Recognize that energy can change forms but the total amount of energy remains constant.

Grade 7 continued

PHYSICAL SCIENCE (PS)

Topic: Conservation of Mass and Energy
This topic focuses on the empirical evidence for the arrangements of atoms on the Periodic Table of Elements, conservation of mass and energy, transformation and transfer of energy.

CONTENT STATEMENT

7.PS.4: Energy can be transferred through a variety of ways.

Mechanical energy can be transferred when objects push or pull on each other over a distance.

Mechanical and electromagnetic waves transfer energy when they interact with matter.

Thermal energy can be transferred through radiation, convection and conduction.

An electrical circuit transfers energy from a source to a device.

Note: *Energy transfers should be experiential and observable at this grade level.*

CONTENT ELABORATION

Prior Concepts Related to Energy Transfer
PreK-2: Temperature changes are observed. The sun is the principal source of energy. It affects the temperature of Earth and supplies life's energy.

Grades 3-5: Objects with energy have the ability to cause change. Electrical, heat, light and sound energy are explored. Earth's resources can be used for energy. Energy is transferred and transformed by organisms in ecosystems.

Grade 6: Energy is identified as kinetic or potential and can transform from one form to another (gravitational, electrical, magnetic, heat, light, sound). Density depends on the mass and volume of a substance. Thermal energy is related to the motion of particles.

Grade 7 Concepts
Mechanical energy is transferred when a force acts between objects to move one of the objects some distance with or against the force. The amount of energy transferred increases as the strength of the force and/or the distance covered by the object increases. This energy transfer (work) stops when the objects no longer exert forces on each other. Energy transfers should be experiential and observable at this grade level.

Waves can be described by their speed, wavelength, amplitude and frequency. Vibrations cause wave-like disturbances that transfer energy from one place to another. Mechanical waves require a material (medium) in which to travel. The medium moves temporarily as the energy passes through it but returns to its original undisturbed position. Mechanical waves are classified as transverse or longitudinal (compressional) depending on the direction of movement of the medium. The energy of a mechanical wave depends on the material and increases with amplitude. While light and other electromagnetic waves do not require a medium and can travel through a vacuum, they can travel through some media, such as clear glass. A wave travels at a constant speed through a particular material as long as it is uniform (e.g., for water waves, having the same depth). The speed of the wave depends on the nature of the material (e.g., sound waves travel faster through most solids than gases). For a particular uniform medium, as the frequency (f) of the wave is increased, the wavelength (λ) of the wave is decreased.

Gravitational potential energy is associated with the mass of an object and its height above a reference point (e.g., above ground level, above floor level). A change in the height of an object is evidence that the gravitational potential energy has changed.

Elastic potential energy is associated with how much an elastic object has been stretched or compressed and how difficult such a compression or stretch is. A change in the amount of compression or stretch of an elastic object is evidence that the elastic potential energy has changed.

Chemical potential energy is associated with the position and arrangement of the atoms within substances. Rearranging atoms into new positions to form new substances (chemical reaction) is evidence that the chemical potential energy has most likely changed. The energy transferred when a chemical system undergoes a reaction is often thermal energy.

Electrical potential energy is associated with the position of electrically charged objects relative to each other and the amount of charge they have. A change in the position of charged particles relative to each other is evidence of a change in electrical potential energy.

Generators convert mechanical energy into electrical energy and are used to produce electrical energy in power plants. Electric motors convert electrical energy into mechanical energy.

For grade 7, investigation and experiments (3-D and virtual) are used to connect energy transfer and waves to the natural world. Real wave data (e.g., oceanic, seismic, light, sound) can be used.

Heat is the transfer of energy from a warmer object to a cooler one. Thermal energy can be transferred when moving atoms collide. This energy transfer is conduction. Thermal energy can also be transferred by means of thermal currents in air, water or other fluids. As fluids are heated, they expand, decreasing the density. Cooler material with a greater density sinks while warmer material with less density rises, causing currents that transfer energy. This energy transfer is convection. Thermal energy can also be transformed into waves that radiate outward. This radiation can be absorbed by an object and transformed back into thermal energy. This energy transfer is radiation. Technology (e.g., virtual simulations, satellite imagery, remote sensing, accessing real-time temperature data) can be used to demonstrate the transfer of thermal energy on the surface or interior of Earth and within the solar system.

An electric circuit exists when an energy source (e.g., battery, generator, solar cell) is connected to an electrical device (e.g., light bulb, motor) in a closed circuit. The energy source transfers energy to charges in the circuit. Charges flow through the circuit. Electric potential is a measure of the potential electrical energy of each charge. Differences in voltages can be measured with a voltmeter. The energy source does not create the charges; they were already present in the circuit. When the charges reach an electrical device, energy can be transformed into other forms of energy (e.g., light, sound, thermal, mechanical). The voltage drops after this energy transfer, but the charges continue to move through the circuit. In an open circuit, the charges stop flowing and energy is not transferred. Current is the rate of charge flow through conductors and can be measured with an ammeter. The degree to which current is opposed in a circuit is called resistance. Generally, for a particular energy source, the greater the resistance, the lower the current. The resistance through a wire depends upon the type of metal, the length of the wire and the diameter of the wire. Electrical devices can be connected in a series or as a parallel circuit. As the number of devices in a series loop increases, the current in the loop decreases. As loops are added in parallel, the current though the devices in each loop is the same as it would be if that loop were the only loop in the circuit. Many of the circuits used in modern devices involve arrangements of circuit elements that are much more complex than a simple series or parallel circuit. Testing and experimenting (3-D or virtually) with electrical circuits to observe results of energy transfers due to changes in resistance, current and voltage are encouraged.

Note 2: *The electromagnetic nature of electromagnetic radiation is not appropriate at this grade level nor are mathematical calculations of work or electricity.*

Future Application of Concepts
Grade 8: Seismic waves are explored.

High School: Energy and work are explored mathematically.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Parallel and series circuits			
	Use an ammeter to measure the amount of electric current flowing through different positions of series and parallel circuits. Formulate a general rule about the current in series or parallel circuits.	Trace the current flow in parallel and series circuits. Compare the results for parallel and series circuits.	Explain why current is the same at all parts of a series circuit. Explain why the flow of current varies in different parts of a parallel circuit.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Energy transfer in a device			
Pinball Machine			
Design a way to give a steel marble the most possible potential energy in a pinball machine before it is launched.	Compare the amount of energy of pinball machines designed by the different groups. Formulate a hypothesis about which design features provide the marble with the most potential energy. Analyze data to determine patterns and trends between design and effectiveness. Formulate a hypothesis about what design features are most effective.	Explain which design features affect the amount of potential energy given to the ball. Create a design portfolio documenting the design process (e.g., prototypes, modifications, technical drawings, testing, results). Represent the design with a labeled picture constructed with design software. Orally present the design to the class, explaining how energy is transferred at each step.	Explain how mechanical energy is transferred in a pinball machine.
Candle wheel			
Design and construct a candle wheel that will turn a maximum number of times in one minute. Test the designs from the class to determine the effectiveness of each one. Anticipate two applications in which the concepts addressed in this design could be used in the real world.	Test potential components of a candle wheel to determine relationships between the material/design of the component and the effectiveness in allowing maximum energy transfer. Use test results to choose appropriate components for the candle wheel design.	Create a promotional presentation for the candle wheel. Include documentation of the design process (e.g., prototypes, testing, redesign, technical drawings), energy transfers involved and applications for the device.	Recognize that thermal energy can be converted to mechanical energy. Use a particle model of matter to explain how energy can be transferred through convection. Explain how energy is transferred in a candle wheel.
Gravitational potential energy			
	Plan and implement an investigation to determine the relationship between the height/mass of a metal sphere and the amount of change it can make to sand that is held in a container. Determine how to quantify the changes to the sand. Formulate a conclusion about how the height/mass of an object is related to its potential energy.	Graphically represent the data from the investigation in demonstrating science knowledge. Support the conclusion with data from the experiment.	Show how gravitational potential energy is affected by height and mass.

Grade 7 continued

LIFE SCIENCE (LS)

Topic: Cycles of Matter and Flow of Energy
This topic focuses on the impact of matter and energy transfer within the biotic component of ecosystems.

CONTENT STATEMENT

7.LS.1: Energy flows and matter is transferred continuously from one organism to another and between organisms and their physical environments.

Plants use the energy in light to make sugars out of carbon dioxide and water (photosynthesis). These materials can be used or stored for later use. Organisms that eat plants break down plant structures to release the energy and produce the materials they need to survive. The organism may then be consumed by other organisms for materials and energy.

Energy can transform from one form to another in living things. Animals get energy from oxidizing food, releasing some of its energy as heat.

The total amount of matter and energy remains constant, even though its form and location change.

Note: *Chemical reactions in terms of subatomic structures of atoms are not appropriate at this grade level. Chemical reactions are presented as the rearrangement of atoms in molecules.*

CONTENT ELABORATION

Prior Concepts Related to Cycles of Matter and Flow of Energy
Grades 3-5: Conservation of matter is introduced. Populations of organisms can be categorized by how they acquire energy. Food webs can be used to identify the relationships among organisms. Energy entering ecosystems as sunlight is transferred and transformed by producers into energy that organisms use through the process of photosynthesis. That energy then passes from organism to organism as illustrated in food webs.

Grade 6: Atomic Molecular Theory, Cell Theory and the function of cell organelles, including mitochondria and chloroplasts, are studied.

Grade 7 Concepts
The basic concepts for matter and energy flow were introduced in grades 3-5. The grades 3-5 concepts are expanded to include a comparison of photosynthesis and cellular respiration.

The use of light energy to make food is called photosynthesis. The breakdown of food to release the stored energy is called respiration. General formulas are appropriate at this grade level, because atoms and molecules are taught in grade 6. Details of both processes are not grade appropriate. In grade 6, cellular organelles are introduced. It is appropriate to reinforce that the chloroplast (the plant cell organelle that contains chlorophyll) captures the sun's energy to begin the process of converting the energy from the sun into sugars and sugar polymers, such as starch.

As matter is cycled within the environment, it promotes sustainability. The elements that make up the molecules of living things are continuously recycled. Energy-rich molecules that are passed from organism to organism are eventually recycled by decomposers back into mineral nutrients usable by plants. The emphasis is not on food webs, but on the transfer of matter and energy between organisms. The concepts of conservation of matter and conservation of energy are applied to ecosystems. Matter within an ecosystem is continually undergoing changes in form and location; however, as long as it remains within that ecosystem, the total amount of matter in the ecosystem remains constant. An energy pyramid graphic can illustrate the flow of energy. At each stage in the transfer of energy within an ecosystem, some energy is stored in newly synthesized molecules and some energy is transferred into the environment as heat produced by the chemical processes in cells. This dissipated energy is not easy to detect or recapture but continues to exist.

New discoveries, technology and research are used to connect the concept of energy transfer and transformation within the ecosystem and between ecosystems. For example, the use of biomass as an alternative energy source for the local area can focus on different types of biomass, competition between human food crops and biomass crops, and biomass vs. other types of alternatives to fossil-fuels energy.

Future Application of Concepts
High School: The chemical flow of energy during reactions will be explored as the molecular structure of molecules is studied.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Flow of matter and energy			
Ethanol, a plant product, is used in place of fossil fuels. Research the effects of production and usage over the past decade. Evaluate the pros and cons of using biomass products such as ethanol vs. traditional fossil fuels.	Plan and conduct an investigation to determine what factors impact photosynthesis in plants that live in aquatic habitats (e.g., Elodea).	Distinguish between photosynthesis and respiration and illustrate how the two processes are connected. Create a chart that compares the reactants and products of both processes. Trace the flow of energy through the human digestive system showing how food is broken down to release energy through the process of digestion and then through cellular respiration.	Identify the cellular structures primarily responsible for photosynthesis and respiration. Trace and explain how matter and energy are transferred through an ecosystem.

Grade 7 continued

LIFE SCIENCE (LS)

Topic: Cycles of Matter and Flow of Energy
This topic focuses on the impact of matter and energy transfer within the biotic component of ecosystems.

CONTENT STATEMENT	CONTENT ELABORATION
7.LS.2: In any particular biome, the number, growth and survival of organisms and populations depend on biotic and abiotic factors. The variety of physical (abiotic) conditions that exists on Earth gives rise to diverse environments (biomes) and allows for the existence of a wide variety of organisms (biodiversity). Biomes are regional ecosystems characterized by distinct types of organisms that have developed under specific soil and climatic conditions. Ecosystems are dynamic in nature; the number and types of species fluctuate over time. Disruptions, deliberate or inadvertent, to the physical (abiotic) or biological (biotic) components of an ecosystem impact the composition of an ecosystem.	**Prior Concepts Related to Biomes** **PreK-2:** Plants and animals have traits that improve their chances of survival in different environments. Living things have basic needs, which are met by obtaining materials from the physical environment. **Grades 3-5:** Populations of organisms can be categorized by how they acquire energy. Food webs can be used to identify the relationships among organisms. Energy entering ecosystems as sunlight is transferred and transformed by producers into energy that organisms use through the process of photosynthesis. That energy then passes from organism to organism as illustrated in food webs. Predator-prey and producer-consumer relations are addressed in grade 5. **Grade 7 Concepts** Biomes are defined by abiotic components of the environment – topography, soil types, precipitation, solar radiation and temperature. Comparing the different biomes found on Earth is the focus of this content statement. Examples of the Earth's biomes include aquatic (freshwater, brackish water and marine water), forest (tropical and temperate), desert (cold and hot), grassland, taiga and tundra. Biomes should be linked to climate zones on a global level by using a variety of maps, models and technology (e.g., remote sensing, satellite images, LANDSAT). An ecosystem is composed of linked and fluctuating interactions between biotic and abiotic factors. Given adequate resources and an absence of disease or predators, populations of organisms in ecosystems increase at rapid rates. Finite resources and other factors limit population growth. As one population proliferates, it is held in check by one or more environmental factors (e.g., depletion of food or nesting sites, increased loss to predators, invasion by parasites). If a natural disaster such as a flood or fire occurs, the damaged ecosystem is likely to recover in a succession of stages that eventually results in a system similar to the original one. **Future Application of Concepts** **High School:** The evolutionary mechanisms that build unity and diversity are studied.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Ecosystems			
Analyze or critique the impact of Ohio's wetland mitigation plans on a local community or the state as a whole. Include real-world data from the sites in the analysis or critique. Anticipate future trends on the flora and fauna in the ecosystem based upon the real-world data.	Monitor the local ecosystem (e.g., stream, river, construction site) for the impact Ohio's wetland mitigation plans have on water quality (e.g., oxygen levels, pH, phosphorus levels, nitrogen levels) and how the plans will impact living organisms (e.g., algae, diatoms, mussels, insect larvae).	Research an endangered species and examine environmental conditions that may contribute to that organism's classification. Determine if any conservation efforts have been employed and document whether or not any efforts have been successful. Use evidence to support responses. Compare biomes to identify common abiotic factors that support life.	Identify the biotic and abiotic elements of the major biomes and describe how these elements impact each other. Explain how the abiotic factors support the types of organisms that can survive in an environment. Explain the differences between the environment, a biome, an ecosystem and a habitat.

Grade 8

INTRODUCTION TO CONTENT STATEMENTS

GRADE BAND THEME: ORDER AND ORGANIZATION

This theme focuses on helping students use scientific inquiry to discover patterns, trends, structures and relationships that may be inferred from simple principles. These principles are related to the properties or interactions within and between systems.

STRANDS

Strand Connections: Systems can be described and understood by analysis of the interaction of their components. Energy, forces and motion combine to change the physical features of Earth. The changes of the physical Earth and the species that have lived on Earth are found in the rock record. For species to continue, reproduction must be successful.

EARTH AND SPACE SCIENCE (ESS)	PHYSICAL SCIENCE (PS)	LIFE SCIENCE (LS)
Topic: Physical Earth This topic focuses on the physical features of Earth and how they formed. This includes the interior of Earth, the rock record, plate tectonics and landforms.	**Topic: Forces and Motion** This topic focuses on forces and motion within, on and around the Earth and within the universe.	**Topic: Species and Reproduction** This topic focuses on continuation of the species.
CONDENSED CONTENT STATEMENTS		
8.ESS.1 The composition and properties of Earth's interior are identified by the behavior of seismic waves. **8.ESS.2** Earth's lithosphere consists of major and minor tectonic plates that move relative to each other. **8.ESS.3** A combination of constructive and destructive geologic processes formed Earth's surface. **8.ESS.4** Evidence of the dynamic changes of Earth's surface through time is found in the geologic record.	**8.PS.1** Objects can experience a force due to an external field such as magnetic, electrostatic or gravitational fields. **8.PS.2** Forces can act to change the motion of objects.	**8.LS.1** Diversity of species, a result of variation of traits, occurs through the process of evolution and extinction over many generations. The fossil records provide evidence that changes have occurred in number and types of species. **8.LS.2** Every organism alive today comes from a long line of ancestors who reproduced successfully every generation. **8.LS.3** The characteristics of an organism are a result of inherited traits received from parent(s).

NATURE OF SCIENCE GRADE 6-8

Nature of Science One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.	
Categories	**6-8**
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Apply knowledge of science content to real-world challenges. • Identify questions that can be answered through scientific investigations. • Design and conduct scientific investigations using appropriate safety techniques. • Use appropriate mathematics, tools and techniques to gather data and information. • Analyze and interpret data. • Develop descriptions, models, explanations and predictions. • Think critically and logically to connect evidence and explanations. • Recognize and analyze alternative explanations and predictions. • Communicate scientific procedures and explanations. • Design technological/engineering solutions.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	• Science is a way of knowing about the world around us based on evidence from experimentation and observations. • Science is a continual process and the body of scientific knowledge continues to grow and change. • Science assumes that objects and events occur in consistent patterns that are understandable through measurement and observation. • Science should carefully consider and evaluate all data including outliers. • Science is based on observable phenomena and empirical evidence. • Science disciplines share common rules for obtaining and evaluating empirical evidence.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• Individuals from different social, cultural, and ethnic backgrounds work as scientists and engineers. • Scientists and engineers are guided by habits of mind, such as intellectual honesty, tolerance of ambiguity, skepticism and openness to ideas. • Scientists and engineers rely on human qualities such as persistence, precision, reasoning, logic, imagination and creativity.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• Science explanations are subject to revision and improvement in light of additional scientific evidence or new understanding of scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Complete *Nature of Science* document is found on pages 8-12.

Grade 8 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Physical Earth
This topic focuses on the physical features of Earth and how they formed. This includes the interior of Earth, the rock record, plate tectonics and landforms.

CONTENT STATEMENT

8.ESS.1: The composition and properties of Earth's interior are identified by the behavior of seismic waves.

The refraction and reflection of seismic waves as they move through one type of material to another is used to differentiate the layers of Earth's interior. Earth has a core, a mantle, and a crust. Impacts during planetary formation generated heat.

These impacts converted gravitational potential energy to heat. Earth's core is also able to generate its own thermal energy because of decaying atoms. This continuously releases thermal energy. Thermal energy generated from Earth's core drives convection currents in the asthenosphere.

Note 1: *Radioactive decay is not the focus; this will be discussed in Physical Science and Chemistry.*

Note 2: *At this grade level, analyzing seismograms (e.g., amplitude and lag time) and reading a travel time curve are not the focus. At this grade the properties of seismic waves should be addressed.*

CONTENT ELABORATION

Prior Concepts Related to Earth's Interior
PreK-2: Properties of materials can change due to heating or cooling. Forces change the motion of an object.

Grades 3-5: Matter exists in different states. Heating and cooling can change the state of matter. Heat is a form of energy. Energy can cause motion. Earth's surface is changed in many ways. Light changes direction when it moves from one medium to another; it can be reflected, refracted or absorbed.

Grades 6-7: Matter is made up of atoms. Igneous, metamorphic and sedimentary rocks form in different ways and in different environments. Magma from Earth's interior forms igneous rocks. Position and speed can be measured. Matter and energy can be transferred through Earth's spheres. Energy can be transformed from one form to another. Thermal energy can be transferred through radiation, convection and conduction. Electromagnetic waves transfer energy when they interact with matter. Seismic and oceanic waves are found in physical science, grade 7.

Grade 8 Concepts
It is important to provide background knowledge regarding how scientists know about the structure and composition of the interior of Earth (without being able to see it). Seismic data, graphics, charts, digital displays and cross sections can be used to study Earth's interior. Earth is differentiated into distinct chemical and physical layers. They correspond in the following way [the chemical layer is stated first, followed by the physical layers in parentheses]: the crust (upper lithosphere), the mantle (lower lithosphere, asthenosphere, mesosphere) and the core (outer and inner).

The refraction and reflection of seismic waves, as they travel through the lithosphere to the inner core, is used to identify the different physical layers of Earth's interior. The thicknesses of each layer of Earth can vary and be transitional, depending on composition, density, temperature and pressure, rather than uniform and distinct as often depicted in textbooks.

Earth and other planets in the solar system formed as heavier elements (primarily iron and nickel) coalesced in their centers and formed planetary cores. The less dense, lighter elements (potassium and sodium for example) remained closer to the planetary surface. This is planetary differentiation, a process through which distinct layers with characteristic chemical and/or physical properties are formed. A major period of planetary differentiation occurred in our solar system approximately 4.6 billion years ago (College Board Standards for College Success, 2009). There are three main sources of heat in Earth's interior: primordial heat left over from planetary accretion, the decay of radioactive elements and friction as materials move within the Earth.

In addition to the composition of Earth's interior, the history of the formation of Earth and relationships among energy transfer, energy transformation and convection currents within the mantle and crust are essential in understanding sources of energy.

Future Application of Concepts

High School: Waves (all types), gravitational energy, energy transformation and transfer and radioactivity are studied in greater detail. In addition, Earth's formation and the formation of the solar system are examined as the formation of the universe is introduced.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		Formation of Earth	
		Compare Earth's chemical layers with the physical layers. Include their properties and how they interact. Narrate a journey to Earth's core. Features of the journey could include mode of transportation, length of time in each layer, sights seen and other aspects. Use a density column to illustrate how Earth's layers differentiated during formation.	Create a model that identifies Earth's layers.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		Seismic waves	
Evaluate the best locations for seismographs. Design a seismograph that can be used in a less ideal location (e.g., underwater, areas prone to landslides, local earthquake zone areas, wetlands, etc.).		Interpret characteristics of Earth's interior using a variety of resources (e.g., seismic data, maps, diagrams, models, charts, cross sections).[1] Show how seismic data is used to determine the composition of the interior of Earth. Gather evidence that Earth is not homogeneous by comparing a seismic record section to predicted arrivals from a homogeneous Earth model. [2]	Demonstrate the different seismic wave motions and speeds using a Slinky®. Create a graphic organizer comparing p- and s-waves.

[1] Iris: Shadow Zone
[2] Iris: Earth's Layers

Grade 8 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Physical Earth
This topic focuses on the physical features of Earth and how they formed. This includes the interior of Earth, the rock record, plate tectonics and landforms.

CONTENT STATEMENT

8.ESS.2: Earth's lithosphere consists of major and minor tectonic plates that move relative to each other.

Historical data and observations such as fossil distribution, paleomagnetism, continental drift and seafloor spreading contributed to the theory of plate tectonics. The rigid tectonic plates move with the molten rock and magma beneath them in the upper mantle.

Convection currents in the asthenosphere cause movements of the lithospheric plates. The energy that forms convection currents comes from deep within the Earth.

There are three main types of plate boundaries: divergent, convergent and transform. Each type of boundary results in specific motion and causes events (such as earthquakes or volcanic activity) or features (such as mountains or trenches) that are indicative of the type of boundary.

CONTENT ELABORATION

Prior Concepts Related to Forces, Movement and Igneous Environments
PreK-2: Properties of materials can change. Pushing and pulling can affect the motion of an object.

Grades 3-5: Forces change the motion of an object. Rocks have specific characteristics. Heat is a form of energy. Energy can be transferred and transformed. Earth's surface has specific characteristics. Gravitational force and magnetism are studied.

Grades 6-7: Rocks have characteristics that are related to the environment in which they form. Thermal energy is a measure of the motion of the atoms and molecules in a substance. Energy can be transferred, transformed and is conserved. Thermal energy can be transferred through radiation, convection and conduction.

Grade 8 Concepts
Historical data related to the modern-day theory of plate tectonics, which led to theories of continental drift (Wegener), convection theory (Holmes) and seafloor spreading (Hess, Deitz) is introduced. The data supporting these theories include paleontological data, paleoclimate data, paleomagnetic data and the continental "puzzle-like-fit" noticed as early as Magellan and by other mapmakers and explorers. Contemporary data is introduced, including seismic data, GPS/GIS data (documenting plate movement and rates of movement), robotic studies of the sea floor and further exploration of Earth's interior.

Physical world maps, cross sections, models (virtual or 3D) and data are used to identify plate boundaries, movement at the boundary and the resulting feature or event. The relationship between heat from Earth's interior, convection in the magma and plate movement is explored. World distribution of tectonic activity of possible interest should be investigated (e.g., Ring of Fire, San Andreas Fault, Mid-Atlantic Ridge, Mariana Trench, Hawaiian Islands, New Madrid Fault System).

Volcanic activity, earthquakes, tsunamis, geysers, hot springs, faults, oceanic vents, island arcs, hot spots and rift valleys are included in the identification of plates and plate boundaries. Plate boundary identification (convergent, divergent, transform) is based on the resulting features or events. The focus is on the cause of plate movement, the type and direction of plate movement and the result of the plate movement, not on memorizing plate names.

Future Application of Concepts
High School: Thermal energy, gravitational energy, radioactive decay and energy transfer are studied in more depth. In Physical Geology, further studies of plate tectonics, seismology and volcanism are found.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Historical data			
	Investigate, using magnetic data from new technology and the rock record, the pattern of reversing magnetism within Earth's core. Generate a chart or graph to represent findings. Using historical data, predict a time range for when the next reversal could occur. Discuss what impact the reversal could have for humans.	Use rock and fossil data to recreate the position of the continents at various points in history. Graph the age of the Hawaiian Islands and other seamounts and their distance from Kilauea to determine the speed and direction the Pacific Plate is moving due to plate tectonics.[1] Model seafloor spreading at mid-ocean ridges. Map the age of the seafloor.	Describe the historical evidence for plate tectonics, including the early observations, discoveries and ideas that combined to eventually lead to the modern theory of plate tectonics. Make a timeline to show the development of our current theory of plate tectonics. Differentiate between plate tectonics and continental drift.
Mechanisms for movement			
Research and determine the effectiveness of current warning systems in tectonically active regions (e.g., the design of devices and their locations). Suggest changes or improvements.	Research the implications of plate tectonics and produce an artifact to answer one or more of the following questions: 1. What consequences might be encountered if the continents joined together again (Pangaea Ultima)? 2. What will Earth look like in 250 million years? How will the distribution of living things change?	Measure the difference in density between granite and basalt; analyze the role of density in lithospheric interaction. Using a world map, mark the locations of earthquakes and volcanoes that are recorded each week for one month (or longer). Use a different color or pattern so that earthquakes and volcanoes can be differentiated. Outline the boundaries of where the concentrations are	Determine types of plate boundaries based on geologic data (e.g., location and magnitude of earthquakes and volcanoes, elevation and age of ocean crust). Explain the mechanism for plate movement (convection currents in the asthenosphere). Recognize that oceanic crust is more dense and thinner than continental crust.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	3. What fossils might paleontologists find in the future that would help them map locations of Earth's continents during the 21st century? 4. Where is the best place to live to avoid natural disasters caused by tectonic plates? Research the most recent measurements of North America. Using this data and the movement of North America throughout geologic time, predict where North America will be in 600 million years or more. Create a model to demonstrate that movement.	located. Compare/contrast this map with a map of plate boundaries. Ask: What types of boundaries are found in the volcano areas? What types are found in earthquake areas?	Observe the depths of earthquake foci for different types of plate boundaries.[2] Model movements at different plate boundaries (convergent, divergent and transform) and lithospheric interactions (continental-continental, continental-oceanic and oceanic-oceanic) using manipulatives.

[1]Hawaiian Island Age- Hot Spot Activity

[2]Earthquake Browser Iris IEB

Grade 8 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Physical Earth
This topic focuses on the physical features of Earth and how they formed. This includes the interior of Earth, the rock record, plate tectonics and landforms.

CONTENT STATEMENT	CONTENT ELABORATION
8.ESS.3: A combination of constructive and destructive geologic processes formed Earth's surface. Earth's surface is formed from a variety of different geologic processes, including but not limited to plate tectonics.	**Prior Concepts Related to Earth's Surface** **PreK-2:** Water can be found in many forms and locations. Wind is air in motion. **Grades 3-5:** Characteristics of rocks and soil, weathering, deposition, erosion, landforms, mass movement and weather events (e.g., flooding) are studied. **Grades 6-7:** Igneous, metamorphic and sedimentary rock formation, interactions between Earth systems and patterns of erosion and deposition are studied. **Grade 8 Concepts** The interactions between the hydrosphere and lithosphere are studied as they relate to erosional events (e.g., flooding, mass movement). The characteristics of rocks and soil, climate, location, topography and geologic process are studied. Distinguishing between major geologic processes (e.g., tectonic activity, erosion, deposition) and the resulting feature on the surface of Earth is the focus of this content statement. It is important to build on what was included in the elementary grades (recognizing features), enabling students to describe conditions for formation. Topographic, physical and aerial maps, cross-sections, field trips and virtual settings are methods of demonstrating the structure and formation of each type of feature. Technology (e.g., remote sensing, satellite data, LANDSAT) can be used to access real-time photographs and graphics related to landforms and features. Factors that affect the patterns and features associated with streams and floodplains (e.g., discharge rates, gradients, velocity, erosion, deposition), glaciers (e.g., moraines, outwash, tills, erratics, kettles, eskers), tectonic activity (includes the features listed in the previous content statement), coastlines, flooding and deserts should be studied. **Future Application of Concepts** **High School:** Gravitational forces and movement of matter are explored. In Physical Geology, glaciation, sedimentation, stream evolution, seismology, volcanism, bathymetry and further information about weathering, erosion and deposition are included.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Erosion and deposition			
Research and develop a regional solution to minimize the impacts of mass movement events (e.g. flooding, landslides, mudflows, sinkholes, rockfalls).	Devise a stream table and use it to model factors (e.g., glacial activity, gradient, discharge rate, load) and test rates of erosion and deposition in a stream meander over time.	Use current event articles to find examples of gradual and catastrophic destructive processes (e.g., creep vs. landslide).	Label sets of images as erosion or deposition. Identify examples of destructive geologic processes (e.g., flooding, mass wasting, volcanic activity, glacial movement, earthquakes, tsunamis.
Topography			
Research a specific area with active geologic processes or events. Develop a plan to harness the available energy (e.g., heat from magma, water movement) from the geologic activity. Build a working model using specific data, including from the geologic record, about the location. Use the model to evaluate the efficiency of the type of energy chosen.	Design a model of karst topography enabling a 3-D view of a cave or sinkhole. Research the processes that must occur to form karst topography.	Using a topographic map or simulation, explain the processes that created glacial features (e.g., moraines, outwash, fills, erratics, kettles, eskers). Use *Google Earth* to identify the location of features created by glaciers. Compare to a topographic map. Make a claim about the role of glaciers in reshaping the physical landscape of Ohio. Support that claim with topographic and/or surface geologic evidence and reasoning.	Identify features of a surface using a topographic map. Compare topographic features between locations of glaciated and unglaciated Ohio.

Grade 8 continued

EARTH AND SPACE SCIENCE (ESS)

Topic: Physical Earth
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CONTENT STATEMENT

8.ESS.4: Evidence of the dynamic changes of Earth's surface through time is found in the geologic record.

Earth is approximately 4.6 billion years old. Earth history is based on observations of the geologic record and the understanding that processes observed at present day are similar to those that occurred in the past (uniformitarianism). There are different methods to determine relative and absolute age of some rock layers in the geologic record. Within a sequence of undisturbed sedimentary rocks, the oldest rocks are at the bottom (superposition). The geologic record can help identify past environmental and climate conditions.

CONTENT ELABORATION

Prior Concepts Related to Rocks and Fossils
PreK-2: Some living things that once lived on Earth no longer exist because their needs were not met.

Grades 3-5: Rocks have characteristics and form in different ways. Earth's surface changes. Most types of organisms that have lived on Earth no longer exist. Fossils provide a point of comparison between the types of organisms that lived long ago and those living today. Rocks can change size and shape due to weathering. Ice can physically remove and carry rock, soil and sediment.

Grades 6-7: Igneous, metamorphic and sedimentary rocks form in different ways. Each type of rock can provide information about the environment in which it was formed.

Grade 8 Concepts
Representations of the age of Earth should include a graphic demonstration of the immensity of geologic time, as this is a very difficult concept to grasp. The different methods used to determine the age of Earth are an important factor in this concept. In elementary grades, fossils are used to compare what once lived to what lives now, but the concept of Earth's age and the age of the fossils were not included (the concept of billions or millions of years was not age-appropriate). In grade 8, the concept of index fossils is a way to build toward understanding relative dating. Superposition, cross-cutting relationships and index fossils play an important role in determining relative age. Radiometric dating plays an important role in absolute age. The inclusion of new advances and studies is important in learning about the geologic record.

Uniformitarianism can be an important key in understanding how scientists have interpreted the environmental conditions that existed throughout Earth's history. Fossil evidence also can indicate specific environments and climate conditions that help interpret the geologic record. Environmental and climate conditions can also be documented through the cryosphere as seen through ice cores. Relating Earth's climate history to present-day climate issues should include evidence from ice core sampling as well as evidence from the geologic record.

Using actual data to generate geologic maps of local or statewide formations can connect to the real world. Field studies or geologic research (virtual/digital) can help identify local formations and interpret the environment that existed at the time they were formed. Analyzing and interpreting the data to draw conclusions about geologic history is an important part of this content statement.

Future Application of Concepts
High School: The age of Earth is further explored through learning about the evolution and extinction of species throughout Earth's history. In Physical Geology, the interpretations of sections of the rock record and geologic time periods are explored.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	Uniformitarianism		
	Analyze ice core data to reconstruct a region's past environmental and climate conditions. Identify patterns in ice core data to hypothesize the relative composition of present-day and future ice cores. Conduct a local field study or research the geological record of Ohio (virtual/digital) using the past geologic record and make a claim as to how events in the past shaped present-day Ohio. Provide evidence to support your claim.[1] Use the Ohio geologic record to explain why certain industries (e.g., salt, gravel, gas/oil) are prevalent in Ohio. Investigations can be done virtually or through local field studies (e.g., quarries, mines).	Design a gallery walk of different rock types (e.g., coal, sandstone, limestone, shale, granite, basalt) to illustrate different industrial uses. Share with a lower grade.	Explain the Theory of Uniformitarianism including information about James Hutton and Siccar Point, Scotland.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Rock record			
		Arrange rock layers based on index fossils. Determine which radiometric dating method would be best to use for a given fossil.	Recognize the immensity of the geologic time scale.

[1] ODNR: Ohio Geologic Record Data

Grade 8 continued

PHYSICAL SCIENCE (PS)

Topic: Forces and Motion
This topic focuses on forces and motion within, on and around the Earth and within the universe.

CONTENT STATEMENT	CONTENT ELABORATION
8.PS.1: Objects can experience a force due to an external field such as magnetic, electrostatic, or gravitational fields. Magnetic, electrical and gravitational forces can act at a distance.	**Prior Concepts Related to Forces** **PreK-2:** Forces are introduced as pushes and pulls that can change the motion of objects. Magnetic, gravitational and electrical forces act without touching. **Grades 3-5:** The amount of change in movement of an object is based on the mass of the object and the amount of force exerted. The speed of an object is defined and calculated. **Grades 6-7:** An object's motion can be described by its speed and the direction in which it is moving. An object's position and speed can be measured and graphed as a function of time. **Grade 8 Concepts** This content statement involves a basic introduction to the field model. A field model can be used to explain how two objects can exert forces on each other without touching. Details about the field model are not required other than the idea that a field is a concept that is used to understand forces that act at a distance. An object is thought to have a region of influence, called a field, surrounding it. When a second object with an appropriate property is placed in this region, the field exerts a force on and can cause changes in the motion of the object. In grade 8, content will focus on connecting and organizing prior knowledge using the field model. Three types of fields should be investigated: gravitational, electric and magnetic. Every object with mass exerts a gravitational force on every other object with mass. These forces are hard to detect unless at least one of the objects is very massive (e.g., sun, planets). The gravitational force increases with the mass of the objects, decreases rapidly with increasing distance and points toward the center of objects. Weight is the force that a mass experiences in a gravitational field. Weight is often confused with mass. Weight is proportional to mass, but depends upon the gravitational field at a particular location. An object will have the same mass when it is on the moon as it does on Earth. However, the weight (force of gravity) will be different at these two locations. Electrostatic fields exist around objects with a net charge. If a second object with a net charge is placed in the field, the two objects experience electric forces that can attract or repel them, depending on the sign of the charges involved. Magnetic fields exist around magnetic objects. If a second magnetic object is placed in the field, the two objects experience magnetic forces that can attract or repel them, depending on the orientation of the objects involved. Magnetic field lines can be seen when iron filings are sprinkled around a magnet.

Electricity is related to magnetism. In some circumstances, magnetic fields can produce electrical currents in conductors. Electric currents produce magnetic fields. Electromagnets are temporary magnets that lose their magnetism when the electric current is turned off. Building an electromagnet to investigate magnetic properties and fields can demonstrate this concept.

Note 1: *Magnetic poles are often confused with electric charges. It is important to emphasize the differences.*

Note 2: *Mathematics is not used to describe fields at this level.*

Future Application of Concepts
High School: The strength of the force between two charges is calculated using Coulomb's Law. Electromagnetic induction is applied to generators and motors. DC circuits are studied.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	Fields of non-contact forces		
		Use a graphic organizer to compare the interactions of two charged objects, two magnets and two uncharged objects with mass.	Differentiate between electric charges and magnetic poles. Given a simple interaction between two objects that are not touching (e.g., a ball falling to the ground, a magnet and a steel cabinet, hair and a brush experiencing static), identify the objects involved in the interaction and give the direction of the force on each object.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Magnetic fields			
Design and build a prototype of a device that uses the force of attraction to lift and release an object of a certain mass to assist in the sorting of materials at a recycling center or salvage center.	Design an experiment to test factors that affect the strength of an electromagnet (e.g. number and tightness of coils, size and type of core, current and voltage of circuit, wire type). Investigate the direction of the magnetic field around a variety of objects using compasses, iron filings and/or magnetic field sensors. Compare the relative strengths of magnets by comparing the load they can lift (e.g., paperclips). Use data collected to compare magnets of different shapes.	Build a simple electromagnet to investigate how an electric current generates a magnetic field. Observe and document the patterns of magnetic fields around pairs of magnets (include examples of repulsion and attraction).	Explain that the magnetic force exerted on other objects located in a magnetic field increases as the strength of the magnet increases and decreases as the distance from the magnet increases.
Gravitational fields			
	Plan an investigation to determine how the mass or the distance between objects interacting at a distance impacts the amount of gravitational potential energy that is stored in the system.	Use an example to illustrate that objects with mass create gravitational fields and are attracted to each other with forces that are directly proportional to their mass. Use the field model to explain why an apple will fall toward Earth.	Differentiate between the concepts of mass and weight. Explain how mass and distance affect the magnitude of the gravitational force between two objects.
Electrostatic fields			
Design a device, such as a homemade electroscope, that can detect the presence of an electric charge. Design and build a game board that moves an object using electric charges (e.g., obstacle course, hockey).	Design an investigation or use a simulation to determine the relationship between either distance and force or charge and force for two charges. Analyze the data to determine patterns and trends. Formulate a conclusion about the relationship.	Construct a visual representation of the forces on objects as the type of electric charge and/or distance between them changes.	Identify the behavior of charged objects in an electric field (include examples of repulsion and attraction). Create labeled diagrams and descriptions to communicate how various charged and uncharged objects react in the presence of an electric field.

Grade 8 continued

PHYSICAL SCIENCE (PS)

Topic: Forces and Motion
This topic focuses on forces and motion within, on and around the Earth and within the universe.

CONTENT STATEMENT

8.PS.2: Forces can act to change the motion of objects.

The motion of an object is always measured with respect to a reference point.

Forces can be added. The net force on an object is the sum of all of the forces acting on the object.

If there is a nonzero net force acting on an object, its speed and/or direction will change.

Kinetic friction and drag are forces that act in a direction opposite the relative motion of objects.

CONTENT ELABORATION

Prior Concepts Related to Forces
PreK-2: Forces are introduced as pushes and pulls that can change the motion of objects. Forces are required to change the motion of an object. A greater force on a given object results in a greater change of motion.

Grades 3-5: The amount of change in movement of an object is based on the mass of the object and the amount of force exerted. Balanced and unbalanced forces are introduced.

Grades 6-7: An object's motion can be described by its speed and the direction in which it is moving. An object's position and speed can be measured and its position can be graphed as a function of time.

Grade 8 Concepts
Motion can be described in different ways by different observers (e.g., a pencil held in someone's hand may appear to be at rest, but to an observer in a car speeding by, the pencil may appear to be moving).

When multiple forces act on an object, their combined effort is what influences the object's motion (speed and direction). Forces can cancel to a net force of zero if they are equal in strength and act in opposite directions. Such forces are said to be balanced. If all forces are balanced, the object will maintain its current motion (both speed and direction). This means if the object is stationary, it will remain stationary. If the object is moving, it will continue moving in the same direction and at the same speed. When the net force is nonzero, the forces are unbalanced and the object's motion will change.

The forces acting on an object can be modeled by a force diagram. Forces are represented by arrows drawn on an isolated picture of the object. The direction of each arrow shows the direction of the force. The length of each arrow represents the magnitude of the force. The effect of the net force on the motion of an object can be predicted from a force diagram. The direction and relative size of the net force can be identified from force diagrams involving multiple forces. Diagrams with forces in both the horizontal and vertical directions can be considered. At this grade level, there should be unbalanced forces in only one of these dimensions. Forces can also act to change the direction of objects. If a force on an object acts toward a single center, the object's path may curve into an orbit around the center.

Friction is a force that opposes sliding between two surfaces. For surfaces that are sliding relative to each other, the force on an object always points in the direction opposite the relative motion of the object. This force is known as kinetic friction. Drag is a force that opposes the motion of an object when a solid object moves through a fluid (e.g., gas, liquid). Kinetic friction and drag affect the motion of objects and may even cause moving objects to slow to a stop unless another force is exerted in the direction of motion. A lack of understanding of friction can lead to the misconception that objects require a sustained force to continue moving. Experimentation with objects that have limited friction (e.g., a puck on an air hockey table, dry ice on a surface) can address this misconception. In grade 8, friction will only be calculated from force diagrams. Static friction, as well as the equations for static and kinetic friction, are found in Physics.

Future Application of Concepts
High School: Newton's second law will be developed quantitatively and situations will be explored mathematically.

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		Frame of reference	
		Describe the motion of an object based on multiple reference points.	Recognize that the motion of objects is determined with respect to a fixed reference point.
		Effects of forces acting on objects	
Design and build a simple model, using Newton's first law of motion, to demonstrate the benefits of seatbelts. Use the model to compare the effectiveness of shoulder and lap belts vs. lap belts alone.	Explore the effect of multiple forces on the motion of objects (e.g., cars or marbles and ramps, student tug-o-war, spring launchers with different force amounts). Investigate how opposing forces affect motion in a system consisting of two weights connected by a string hanging over a pulley.	Predict the combined effect (e.g., speed up, slow down, turn left, turn right) of several forces on an object at rest or an object moving in a straight line.	Create a force diagram to illustrate the combined forces acting on an object. Explain how the force of gravity can be acting on a book at rest on a table and yet the book does not move. Recognize that free fall results from the gravitational attraction between Earth and an object.
		Friction	
Improve the design of a component or system to reduce/increase the effects of friction on a moving object (e.g., tire, fishing reel, ski, skateboard, bicycle).	Investigate the relationship between the type of surface and the effects of kinetic friction on moving objects (e.g., experiment with moving an object across various surfaces). Determine what type of force is needed to get a moving puck on an air hockey table to slow down, speed up or move in a circle.	Identify situations where friction is beneficial, detrimental or both.	Explain that friction opposes the motion of objects.

Grade 8 continued

LIFE SCIENCE (LS)

Topic: Species and Reproduction
This topic focuses on continuation of the species.

CONTENT STATEMENT

8.LS.1: Diversity of species, a result of variation of traits, occurs through the process of evolution and extinction over many generations. The fossil records provide evidence that changes have occurred in number and types of species.

Fossils provide important evidence of how life and environmental conditions have changed.

Changes in environmental conditions can affect how beneficial a trait will be for the survival and reproductive success of an organism or an entire species.

Throughout Earth's history, extinction of a species has occurred when the environment changes and the individual organisms of that species do not have the traits necessary to survive and reproduce in the changed environment. Most species (approximately 99 percent) that have lived on Earth are now extinct.

Note: *Population genetics and the ability to use statistic mathematics to predict changes in a gene pool are reserved for high school Biology.*

CONTENT ELABORATION

Prior Concepts Related to Species and Reproduction
PreK-2: Living things have physical traits that enable them to live in different environments. Some kinds of individuals that once lived on Earth have completely disappeared, although they may be something like others that are alive today.

Grades 3-5: Fossils provide a point of comparison between the types of organisms that lived long ago and those existing today.

Grades 6-7: In a biome, the number, growth and survival of organisms and populations depend on biotic and abiotic conditions.

Grade 8 Concepts
The fossil record documents the variation in a species that may have resulted from changes in the environment. The fossil record is contained within the geologic record (ESS grade 8). Combining data from the geologic record and the fossil record, Earth's living history can be interpreted. Data and evidence from the fossil record can be used to further develop the concepts of extinction, biodiversity and the diversity of species. The term "transitional form" is used to describe intermediate organisms between ancestral forms and their descendants. Some examples of transitional forms were fossilized and found in the fossil record. Other transitional forms are missing from the fossil record.

Evidence from the geologic and fossil record can be used to infer what the environment was like at the time of deposition. The variations that exist in organisms can accumulate over many generations, so organisms can be very different in appearance and behavior from their distant ancestors. Diversity can result from sexual reproduction. The sorting and combination of genes result in different genetic combinations, which allow offspring to be similar to, yet different from, their parents and each other (this statement connects to the grade 8 Life Science content statement on reproduction and Mendelian Genetics). These variations may allow for survival of individuals when the environment changes. Diversity in a species increases the likelihood that some individuals will have characteristics suitable to survive and reproduce when conditions change.

Note: *Molecular clocks are not appropriate at this grade level.*

Future Application of Concepts
High School: Diversification of species is explored in more depth.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		Survival advantages	
		Compare the ability of organisms to survive under different environmental conditions. Investigate structural differences in past and present organisms that have enabled some species to survive while others have become extinct due to sudden or gradual environmental changes (e.g., peppered moths, crayfish fossils found in Antarctica). Work with fossils that demonstrate bilateral symmetry. Investigate ways having bilateral symmetry can be an advantage. Consider how having bilateral symmetry benefits humans.	
		Fossils as environmental evidence	
		Use evidence from geologic and fossil records to infer what the environment was like at the time a specific organism lived. Use a model to identify the relative ages of various fossils or rock layers using index fossils.	Define and give examples of index fossils. Map the multiple mass extinction events that have occurred throughout Earth's history. Explain why 99% of all species that have ever existed on Earth are extinct.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Natural selection and biodiversity			
Develop a policy to address the increasing rates of antibiotic or herbicide-resistant infections. Consider the perspectives of various stakeholders (e.g., farmers, government agencies, doctors, land managers).	Conduct a field study on a specific population of plants or animals in a local area. Examine members of that population and record variations in physical characteristics that can be seen (e.g., height, coloration, number of flowers). Predict which traits are more beneficial for survival in the population's current environment. Predict what variations may result in higher survival rates should the environment change (e.g., became warmer, colder, wetter, windier).	Examine organisms that are found in a variety of environments and others that have very specific habitats to determine which have the greater chance of survival when the environment changes. Compare adaptations that allow an organism to survive under different environmental conditions (e.g., specialists like panda bears and their dependency on bamboo or generalists like the raccoon). Use manipulatives to model how selection pressures influence a population. Analyze how the populations change due to these pressures. Graph data that indicates how the biodiversity in a particular biome or continent has changed over time.	Describe how to determine the relative age of fossils found in sedimentary rock. Explain why variation within a population can be advantageous for a population of organisms.

Grade 8 continued

LIFE SCIENCE (LS)

Topic: Species and Reproduction
This topic focuses on continuation of the species.

CONTENT STATEMENT	CONTENT ELABORATION
8.LS.2: Every organism alive today comes from a long line of ancestors who reproduced successfully every generation. Reproduction is the transfer of genetic information from one generation to the next. It can occur with mixing of genes from two individuals (sexual reproduction). It can occur with the transfer of genes from one individual to the next generation (asexual reproduction). The ability to reproduce defines living things.	**Prior Concepts Related to Species and Reproduction** **Grades 3-5:** Individual organisms inherit many traits from their parents indicating a reliable way to transfer information from one generation to the next. **Grades 6-7:** Modern Cell Theory states cells come from preexisting cells. **Grade 8 Concepts** Organisms reproduce either sexually or asexually. Some organisms are capable of both. In asexual reproduction, all genes come from a single parent, resulting in offspring genetically identical to their parent. Mitosis was introduced in grade 6. At this grade level, the end products of mitotic and meiotic cell divisions are compared as they relate to asexual and sexual reproduction. Mitosis and meiosis are addressed in preparation for the study of Mendelian genetics in 8.LS.3. In sexual reproduction, a single specialized cell from a female (egg) merges with a specialized cell from a male (sperm). Half of the nuclear genes come from each parent. The fertilized cell, carrying genetic information from each parent, multiplies forming the genetically complete organism. Each cell of an organism contains the same genetic information. As opposed to asexual reproduction, sexual reproduction results in offspring with new combinations of traits which may increase or decrease their chances for survival. **Future Application of Concepts** **High School:** Genetic variation in traits among offspring is a result of the movement of chromosomes crossing over, independent assortment and recombination during gamete formation. The implications of mutation during gamete formation are investigated.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Asexual and sexual reproduction			
Research the use of cloning in agriculture. Identify a problem that was solved by cloning and possible benefits and issues that can occur because of the use of cloning in that example, supporting your ideas with scientific evidence.	Examine offspring in plants that are produced sexually. Note and record variations that appear. Determine how the variations may help an organism to survive if the environment should change (e.g., warmer or cooler temperatures, increase or decrease in precipitation).	Use microscopes, web-based video or simulations to observe microscopic organisms that reproduce asexually and/or sexually (e.g., paramecium, hydra, aphids, yeast, planaria). Compare sexual and asexual reproduction and discuss the advantages and disadvantages. Compare the processes and end products of mitosis and meiosis. Compare the genetic diversity of the daughter cells from these processes. Explain why genetic variation is a survival advantage. Recognize that human egg and sperm are produced by meiosis. Explain how this is beneficial to humans.	Predict the number of chromosomes in a body cell when given the number in a gamete. Predict the number of chromosomes in a gamete when given the number in a body cell. Explain how the number of chromosomes in a daughter cell is related to the number of chromosomes in the parent cell for mitosis and meiosis. Describe the features of sexual and asexual reproduction related to the transfer of genetic information from parent to offspring.

Grade 8 continued

LIFE SCIENCE (LS)

Topic: Species and Reproduction
This topic focuses on continuation of the species.

CONTENT STATEMENT	CONTENT ELABORATION
8.LS.3: The characteristics of an organism are a result of inherited traits received from parent(s). Expression of all traits is determined by genes and environmental factors to varying degrees. Many genes influence more than one trait, and many traits are influenced by more than one gene. During reproduction, genetic information (DNA) is transmitted between parent and offspring. In asexual reproduction, the lone parent contributes DNA to the offspring. In sexual reproduction, both parents contribute DNA to the offspring. **Note 1:** *The focus should be the link between DNA and traits without being explicit about the mechanisms involved.* **Note 2:** *The ways in which bacteria reproduce is beyond the scope of this content statement.* **Note 3:** *The molecular structure of DNA is not appropriate at this grade level.*	**Prior Concepts Related to Species and Reproduction** **PreK-2:** Offspring tend to look like their parents. **Grades 3-5:** Individual organisms inherit many traits from their parents indicating a reliable way to transfer information from one generation to the next. **Grades 6-7:** Modern Cell Theory states cells come from preexisting cells. **Grade 8 Concepts** The traits of one or two parents are passed on to the next generation through reproduction. Traits are determined by instructions encoded in deoxyribonucleic acid (DNA), which forms genes. Genes have different forms called alleles. The principles of Mendelian genetics are introduced by reviewing Mendel's work. Mendel's two laws provide the theoretical base for future study of modern genetics. Mendel's first law, the Law of Segregation, and his second law, the Law of Independent Assortment, should be demonstrated and illustrated in a variety of organisms. The concepts of dominant and recessive genes are appropriate at this grade level. Codominant traits such as roan color in horses and cows may be useful to provide further validation of the theory and to help dispel some misconceptions. Pedigree analysis is appropriate for this grade level when limited to dominant, recessive or codominance of one trait. The Law of Independent Assortment should only be explored in simple cases of dominant and recessive traits. Incomplete dominance is not suggested for this grade level to help avoid the misconception of "blending of traits." Codominance is encouraged because both traits are expressed in the resulting offspring. Dihybrid crosses and sex-linked traits also are reserved for high school. A long-term investigation to analyze and compare characteristics passed on from parent to offspring through sexual and asexual reproduction can be conducted. These investigations can lead to questions about the phenotypes that appear in the resulting generations and what they infer about genotypes of the offspring. **Future Application of Concepts** **High School:** The details and importance of gamete formation, the structure of DNA and modern genetics are studied.

EXPECTATIONS FOR LEARNING

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This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Inheritance of genetic information			
Research artificial selection (e.g., genetic modification, animal husbandry, gene therapy). Select one practice and determine how that practice has changed the way humans influence the inheritance of desired traits in organisms. Discuss and evaluate the ethics of genetic modification and artificial selection (e.g., drought-resistant crops, designer dogs)	Design and implement an investigation to predict the genotypes and phenotypes of offspring between plants of known heritage (e.g., Wisconsin Fast Plants™, Arabidopsis).	Predict the genotypic and phenotypic ratios for a monohybrid cross with Mendelian dominance and codominance patterns through at least two generations. Determine allele combinations that make it possible for traits to skip generations. Conduct a forensic investigation to explore complete dominance (Rh factors) and codominance (ABO blood type) inheritance patterns.	Describe how DNA, genes, chromosomes and inherited traits are connected. Select a genetic condition and show its inheritance pattern through multiple generations on a pedigree or other graphic representation Select a variety of genetic conditions to explore autosomal dominant, autosomal recessive and codominant inheritance patterns.

Physical Science

INTRODUCTION AND SYLLABUS

COURSE DESCRIPTION

Physical science is a high school level course, which satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires three units of science. Each course should include inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.

Physical science introduces students to key concepts and theories that provide a foundation for further study in other sciences and advanced science disciplines. Physical science comprises the systematic study of the physical world as it relates to fundamental concepts about matter, energy and motion. A unified understanding of phenomena in physical, living, Earth and space systems is the culmination of all previously learned concepts related to chemistry, physics, and Earth and space science, along with historical perspective and mathematical reasoning.

COURSE CONTENT

The following information may be taught in any order; there is no ODE-recommended sequence.

PS.M: STUDY OF MATTER

PS.M.1: Classification of matter
- Heterogeneous vs. homogeneous
- Properties of matter
- States of matter and its changes

PS.M.2: Atoms
- Models of the atom (components)
- Ions (cations and anions)
- Isotopes

PS.M.3: Periodic trends of the elements
- Periodic law
- Representative groups

PS.M.4: Bonding and compounds
- Bonding (ionic and covalent)
- Nomenclature

PS.M.5: Reactions of matter
- Chemical reactions
- Nuclear reactions

PS.EW: ENERGY AND WAVES

PS.EW.1: Conservation of energy
- Quantifying kinetic energy
- Quantifying gravitational potential energy

PS.EW.2: Transfer and transformation of energy (including work)

PW.EW.3: Waves
- Refraction, reflection, diffraction, absorption, superposition
- Radiant energy and the electromagnetic spectrum
- Doppler shift

PS.EW.4: Thermal energy

PS.EW.5: Electricity
- Movement of electrons
- Current
- Electric potential (voltage)
- Resistors and transfer of energy

PS.FM: FORCES AND MOTION

PS.FM.1: Motion
- Introduction to one-dimensional vectors
- Displacement, velocity (constant, average and instantaneous) and acceleration
- Interpreting position vs. time and velocity vs. time graphs

PS.FM.2: Forces
- Force diagrams
- Types of forces (gravity, friction, normal, tension)
- Field model for forces at a distance

PS.FM.3: Dynamics (how forces affect motion)
- Objects at rest
- Objects moving with constant velocity
- Accelerating objects

PS.U: THE UNIVERSE

PS.U.1: History of the universe

PS.U.2: Galaxies

PS.U.3: Stars
- Formation: stages of evolution
- Fusion in stars

NATURE OF SCIENCE HIGH SCHOOL

Nature of Science
One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.

Categories	High School
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Identify questions and concepts that guide scientific investigations. • Design and conduct scientific investigations using a variety of methods and tools to collect empirical evidence, observing appropriate safety techniques. • Use technology and mathematics to improve investigations and communications. • Formulate and revise explanations and models using logic and scientific evidence (critical thinking). • Recognize and analyze explanations and models. • Communicate and support scientific arguments.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	• Various science disciplines use diverse methods to obtain evidence and do not always use the same set of procedures to obtain and analyze data (i.e., there is no one scientific method). o Make observations and look for patterns. o Determine relevant independent variables affecting observed patterns. o Manipulate an independent variable to affect a dependent variable. o Conduct an experiment with controlled variables based on a question or hypothesis. o Analyze data graphically and mathematically. • Science disciplines share common rules of evidence used to evaluate explanations about natural phenomenon by using empirical standards, logical arguments and peer reviews. o Empirical standards include objectivity, reproducibility, and honest and ethical reporting of findings. o Logical arguments should be evaluated with open-mindedness, objectivity and skepticism. • Science arguments are strengthened by multiple lines of evidence supporting a single explanation. • The various scientific disciplines have practices, methods, and modes of thinking that are used in the process of developing new science knowledge and critiquing existing knowledge.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• Science depends on curiosity, imagination, creativity and persistence. • Individuals from different social, cultural, and ethnic backgrounds work as scientists and engineers. • Science and engineering are influenced by technological advances and society; technological advances and society are influenced by science and engineering. • Science and technology might raise ethical, social and cultural issues for which science, by itself, does not provide answers and solutions.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• Science can advance through critical thinking about existing evidence. • Science includes the process of comparing patterns of evidence with current theory. • Some science knowledge pertains to probabilities or tendencies. • Science should carefully consider and evaluate anomalies (persistent outliers) in data and evidence. • Improvements in technology allow us to gather new scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

PS.M: STUDY OF MATTER

PS.M.1: Classification of matter

- Heterogeneous vs. homogeneous
- Properties of matter
- States of matter and its changes

PS.M.2: Atoms

- Models of the atom (components)
- Ions (cations and anions)
- Isotopes

PS.M.3: Periodic trends of the elements

- Periodic law
- Representative groups

PS.M.4: Bonding and compounds

- Bonding (ionic and covalent)
- Nomenclature

PS.M.5: Reactions of matter

- Chemical reactions
- Nuclear reactions

CONTENT ELABORATION: STUDY OF MATTER

PS.M.1: Classification of matter

Matter was introduced in the elementary grades and the learning progression continued through middle school to include differences in the physical properties of solids, liquids and gases. Elements, compounds, mixtures, molecules, kinetic and potential energy and the particulate nature of matter were introduced. Content in Chemistry (e.g., electron configuration, molecular shapes, bond angles) will build on concepts in this course.

Matter can be classified in broad categories, such as homogeneous and heterogeneous, according to its composition or by its chemical properties (e.g., reactivity, flammability, pH) and physical properties (e.g., color, solubility, odor, hardness, density, conductivity, melting point and boiling point, viscosity, malleability). Solutions are homogeneous mixtures of a solute dissolved in a solvent. The amount of a solid solute that can dissolve in a solvent generally increases as the temperature increases since the particles have more kinetic energy to overcome the attractive forces between them. Water is often used as a solvent since so many substances will dissolve in water. Aqueous solutions can be classified as acidic (below 7 on the pH scale), neutral (7 on the pH scale), or basic (above 7 on the pH scale), but the discussion of hydroxide and hydrogen ions as they relate to the pH scale is reserved for Chemistry. Physical properties can be used to separate the substances in mixtures, including solutions.

Phase changes can be represented by graphing the temperature of a sample vs. the time it has been heated. Investigations include collecting data during heating, cooling and solid-liquid-gas phase changes. At times, the temperature will change steadily, indicating a change in the motion of the particles and the kinetic energy of the substance. However, during a phase change, the temperature of a substance does not change, indicating there is no change in kinetic energy. Since the substance continues to gain or lose energy during phase changes, these changes in energy are potential and indicate a change in the position of the particles.

When heating a substance, a phase change will occur when the kinetic energy of the particles is great enough to overcome the attractive forces between the particles; the substance then melts or boils. Conversely, when cooling a substance, a phase change will occur when the kinetic energy of the particles is no longer great enough to overcome the attractive forces between the particles; the substance then condenses or freezes. Phase changes are examples of changes that can occur when energy is absorbed from the surroundings (endothermic) or released into the surroundings (exothermic). When thermal energy is added to a solid, liquid or gas, most substances increase in volume because the increased kinetic energy of the particles causes an increased distance between the particles. This results in a change in density of the material. Generally, solids have greater density than liquids, which have greater density than gases due to the spacing between the particles. The density of a substance can be calculated from the slope of a mass vs. volume graph. Differences in densities can be determined by interpreting mass vs. volume graphs of the substances. Students should be able to calculate mass, volume or density, given two of the three values.

PS.M.2: Atoms
Content introduced in middle school, where the atom was introduced as a small, indestructible sphere, is further developed in this course. Over time, technology was introduced that allowed the atom to be studied in more detail. The atom is composed of protons, neutrons and electrons that have measurable properties, including mass and, in the case of protons and electrons, a characteristic charge. An atom is empty space with a very small positively charged nucleus. The nucleus is composed of protons and neutrons. The electrons move about in the empty space that surrounds the nucleus. Although current understanding goes beyond the Bohr Model, it can still be used to represent the atom and develop the idea of valence electrons. Experimental evidence that led to the development of historic atomic models is reserved for Chemistry.

All atoms of a particular element have the same atomic number; an element may have different isotopes with different mass numbers. Atoms may gain or lose valence electrons to become anions or cations. Atomic number, mass number, charge and identity of the element can be determined from the numbers of protons, neutrons and electrons. Atomic mass calculations and explanations about configuration of electrons and how atomic spectra are produced are reserved for Chemistry**.**

PS.M.3: Periodic trends of the elements
Content from the middle school level, specifically the properties of metals, nonmetals and metalloids and their positions on the periodic table, is further expanded in this course. The periodic table was arranged so that elements with similar chemical and physical properties are in the same group or family. When elements are listed in order of increasing atomic number, the same sequence of properties appears over and over again; this is the periodic law. Trends in simple observable properties, like density or melting point, can be examined within families or groups on the periodic table. These trends allow scientists to make predictions about new elements. Metalloids are elements that have some properties of metals and some properties of nonmetals. Metals, nonmetals, metalloids, periods and groups or families including the alkali metals, alkaline earth metals, halogens and noble gases can be identified by their position on the periodic table. Elements in Groups 1, 2 and 17 have characteristic ionic charges that will be used in this course to predict the formulas of compounds. Other trends in the periodic table (e.g., atomic radius, electronegativity, ionization energies) are reserved for Chemistry.

PS.M.4: Bonding and compounds
Middle school content introduced the concept that compounds are composed of atoms of two or more different elements joined together chemically. In this course, the chemical joining of atoms is studied in more detail. Atoms may be bonded together by losing, gaining or sharing valence electrons to form molecules or three-dimensional lattices. An ionic bond involves the attraction of two oppositely charged ions, typically a metal cation and a nonmetal anion formed by transferring electrons between the atoms. An ion attracts oppositely charged ions from every direction, resulting in the formation of a three-dimensional lattice. Covalent bonds result from the sharing of electrons between two atoms, usually nonmetals. Covalent bonding can result in the formation of structures ranging from small individual molecules to three-dimensional lattices (e.g., diamond). The bonds in most compounds fall on a continuum between the two extreme models of bonding: ionic and covalent.

Using the periodic table to determine ionic charge, formulas of ionic compounds containing elements from groups 1, 2, 17, hydrogen and oxygen can be predicted. Given a chemical formula, a compound can be named using conventional systems that include Greek prefixes where appropriate. Prefixes will be limited to represent values from one to 10. Given the name of an ionic or covalent substance, formulas can be written. Naming organic molecules is beyond this grade level and is reserved for an advanced chemistry course. Prediction of bond types from electronegativity values, polar covalent bonds, and writing formulas/naming compounds that contain polyatomic ions or transition metals are reserved for Chemistry.

PS.M.5: Reactions of matter
In middle school, the law of conservation of matter was expanded to chemical reactions, noting that the number and type of atoms and the total mass are the same before and after the reaction. In this course, conservation of matter is expressed by writing balanced chemical equations. At this level, reactants and products can

be identified from an equation and simple equations can be written and balanced given either the formulas of the reactants and products or a word description of the reaction. Stoichiometric relationships beyond the coefficients in a balanced equation and classification of types of chemical reactions are reserved for Chemistry.

During chemical reactions, thermal energy is either transferred from the system to the surroundings (exothermic) or transferred from the surroundings to the system (endothermic). Since the environment surrounding the system can be large, temperature changes in the surroundings may not be detectable.

Nuclear reactions involve changes to the nucleus and typically produce much larger energies than chemical reactions. The strong nuclear force is an attractive force that binds protons and neutrons together in the nucleus. While the nuclear force is extremely weak at most distances, over the very short distances present in the nucleus the force is greater than the repulsive electrical forces among protons. When the attractive nuclear forces and repulsive electrical forces in the nucleus are not balanced, the nucleus is unstable. Through radioactive decay, the unstable nucleus emits radiation in the form of very fast-moving particles and energy to produce a new nucleus. Nuclei that undergo this process are said to be radioactive. Radioactive decay can result in the release of different types of radiation (alpha, beta, gamma), each with a characteristic mass, charge, and potential to alter and penetrate the material it strikes. Alpha decay changes the identity of the element. Beta decay results from the decay of a neutron. When a radioisotope undergoes alpha or beta decay, the resulting nucleus can be predicted and the balanced nuclear equation can be written.

For any radioisotope, the half-life is unique and predictable. Graphs can be constructed that show the amount of a radioisotope that remains as a function of time and can be interpreted to determine the value of the half-life. Half-life values are used in radioactive dating. Only whole number integers of half-lives will be addressed in this course.

Other examples of nuclear processes include nuclear fission and nuclear fusion. Nuclear fission involves splitting a large nucleus into smaller nuclei, releasing large quantities of energy. Nuclear fusion is the joining of smaller nuclei into a larger nucleus accompanied by the release of large quantities of energy. Nuclear fusion is the process responsible for formation of elements in the universe beyond hydrogen and is the source of energy in the sun and other stars. Using nuclear reactions as an energy resource can be addressed. Further details about nuclear processes, including mass-energy equivalence and nuclear power applications, are addressed in Physics.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PS.M.1: Classification of matter			
Heterogeneous vs. homogeneous			
Devise a method to purify water in developing countries.	Design a procedure to separate a homogeneous or heterogeneous mixture.	Using data from various physical separation techniques, construct a particle diagram for a mixture based on the particulate nature of matter.	Identify samples of matter as homogeneous or heterogeneous (e.g., salt water, chicken noodle soup).
Properties of matter			
	Investigate the effect of various factors (e.g., temperature, surface area of solute, stirring) on the rate materials (e.g., sugar cubes, salt crystals) dissolve.	Explain the process of burning a candle in terms of physical and chemical changes. Compare acids and bases found in the home (e.g., household cleaning products, soaps, coffee, soda, vinegar, fruit juices, antacids) using experimentally determined pH data from meters or from universal indicators.	Explain the location of acids, bases and neutral substances on the pH scale.
States of matter and its changes			
		Using a phase change diagram determine the phase of water and other substances at different temperatures.	Identify the various phase changes and classify them as endothermic or exothermic.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PS.M.2: Atoms			
	Design and implement a procedure to test for the presence of common dissolved ions.	Research cations and anions and how they function in everyday products (e.g., hair products, car washes, dryer sheets). Describe the difference between hard and soft water. Model the formation of ions with particle diagrams or manipulatives. Interpret the presence of dissolved ions in water with respect to human health.	Describe the location, charge, and relative size of a proton, neutron, and electron. Use information from the periodic table to calculate numbers of protons, neutrons and electrons for an element. Use this information to draw a Bohr model of the element. Define isotope and provide an example. Explain the importance of valence electrons. Use the periodic table and/or electron dot diagrams to identify the ionic charge of elements in groups 1, 2, 17, and 18.
PS.M.3: Periodic trends of the elements			
Design an alternate arrangement of elements in the periodic table.		Develop a flow chart or dichotomous key to identify a substance as a metal, nonmetal or metalloid. Explain the differences between the properties/ionic charge of 2 elements chosen from groups 1, 2, 17, and 18.	Using the periodic table and/or electron dot diagrams, identify the ionic charge of elements in groups 1, 2, 17, and 18. Explain why elements are grouped into families. Identify metals, nonmetals, metalloids, alkali metals, alkaline earth metals, halogens and noble gases based on their positions on the periodic table.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PS.M.4: Bonding and compounds			
Bonding (ionic and covalent)			
		Using modeling, compare ionic and covalent compounds in terms of molecular and three-dimensional lattice formation.	Describe how ionic and covalent bonds are formed in terms of valence electrons. Given elements and their locations on the periodic table, predict if they will form ionic or covalent compounds.
Nomenclature			
		Use naming conventions to find an example of a covalent compound and an ionic compound in an ingredient list. Explain why having a standard set of naming and formula writing rules is important.	Name the Greek prefixes 1-10. Given two elements, predict the chemical formula and name of an ionic compound (e.g., calcium and chlorine = $CaCl_2$ = calcium chloride). Name binary covalent molecules and binary ionic compounds when given formulas. Determine the formulas for covalent molecules and binary ionic compounds when given their names.
PS.M.5: Reactions of matter			
Chemical reactions			
		Explain why Na + Br_2 yields NaBr and not $NaBr_2$. Investigate safe chemical reactions (e.g., vinegar and baking soda in a Ziploc bag) to determine if they are exothermic or endothermic.	Give an example where temperature change is observable without measurement, where temperature change is observable with a thermometer, and where temperature change is impossible to measure. Balance a chemical equation when provided the formulas of reactants and products.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Nuclear reactions			
		Use the half-life of C-14 to explain appropriate uses of carbon dating. Describe how the radioactive isotopes of several elements are used in medical testing. Describe the short- and long-term effects of nuclear wastes on the environment. Research and interpret the consequences, information and technology involved in the discovery or synthesis of new elements. Include historical references (e.g., Madame Curie).	Describe alpha, beta and gamma radiation. Compare nuclear fission and nuclear fusion. Identify applications of radioisotopes.

Physical Science continued

PS.EW: ENERGY AND WAVES
PS.EW.1: Conservation of energy

- Quantifying kinetic energy
- Quantifying gravitational potential energy

PS.EW.2: Transfer and transformation of energy (including work)
PS.EW.3: Waves

- Refraction, reflection, diffraction, absorption, superposition
- Radiant energy and the electromagnetic spectrum
- Doppler shift

PS.EW.4: Thermal energy
PS.EW.5: Electricity

- Movement of electrons
- Current
- Electric potential (voltage)
- Resistors and transfer of energy

CONTENT ELABORATION: ENERGY AND WAVES

Building upon knowledge gained in elementary and middle school, major concepts about energy and waves are further developed. Conceptual knowledge will move from qualitative understandings of energy and waves to ones that are more quantitative using mathematical formulas, manipulations and graphical representations.

PS.EW.1: Conservation of energy

Energy content learned in middle school, specifically conservation of energy and the basic differences between kinetic and potential energy, is elaborated on and quantified in this course. Energy has no direction and has units of joules (J). Kinetic energy, E_k, can be mathematically represented by $E_k = ½mv^2$. Gravitational potential energy, E_g, can be mathematically represented by $E_g = mgh$. The amount of gravitational potential energy of an object is measured relative to a reference that is considered to be at a point of zero energy. The reference may be changed to help understand different situations. Only the change in the amount of energy can be measured absolutely. The conservation of energy and equations for kinetic and gravitational potential energy can be used to calculate values associated with energy (e.g., height, mass, speed) for situations involving energy transfer and transformation. Opportunities to quantify energy from data collected in experimental situations (e.g., a swinging pendulum, a car traveling down an incline) should be provided.

PS.EW.2: Transfer and transformation of energy (including work)

In middle school, concepts of energy transfer and transformation were addressed. Topics included conservation of energy, conduction, convection and radiation, the transformation of electrical energy, and the dissipation of energy into thermal energy. Work was introduced as a method of energy transfer into or out of the system when an outside force moves an object over a distance. In this course, these concepts are further developed. As long as the force, F, and displacement, Δx, are in the same or opposite directions, work, W, can be calculated from the equation $W = F\Delta x$. Work can also be quantified as $W = \Delta E$. Energy transformations for a phenomenon can be represented through a series of pie graphs or bar graphs. Equations for work, kinetic energy and potential energy can be combined with the law of conservation of energy to solve problems; conceptual understanding of kinetic energy, potential energy and work should be emphasized. When energy is transferred from one system to another, some of the energy is transformed to thermal energy. Since thermal energy involves the random movement of many trillions of subatomic particles, it is less able to be organized to bring about further change. Therefore, even though the total amount of energy remains constant, less energy is available for doing useful work.

PW.EW.3: Waves
As addressed in middle school, waves transmit energy from one place to another, can transfer energy between objects and can be described by their speed, wavelength, frequency and amplitude. These concepts were applied to seismic waves traveling through different materials. In elementary and middle school, reflection and refraction of light were introduced, as was absorption of radiant energy by transformation into thermal energy. In this course, these processes are conceptually addressed (not mathematically) from the perspective of waves and expanded to include other types of energy that travel in waves. When a wave encounters a new material, the new material may absorb the energy of the wave by transforming it to another form of energy, usually thermal energy. Waves can be reflected off solid barriers or refracted when a wave travels from one medium into another medium. Waves may undergo diffraction around small obstacles or openings. When two waves traveling through the same medium meet, they pass through each other and continue traveling through the medium as before. When the waves meet, they undergo superposition, demonstrating constructive and destructive interference. Sound travels in waves and undergoes reflection, refraction, interference and diffraction. In Physics, many of these wave phenomena will be studied further and quantified. Radiant energy travels in waves and does not require a medium. Sources of light energy (e.g., the sun, a light bulb) radiate energy continuously in all directions. Radiant energy has a wide range of frequencies, wavelengths and energies arranged into the electromagnetic spectrum. The electromagnetic spectrum is divided into bands that have different applications in everyday life: radio (lowest energy), microwaves, infrared, visible light, ultraviolet, X-rays and gamma rays (highest energy).

Radiant energy of the entire electromagnetic spectrum travels at the same speed in a vacuum. Specific frequency, energy, or wavelength ranges of the electromagnetic spectrum are not required. However, the relative positions of the different bands, including the colors of visible light, are important (e.g., ultraviolet has more energy than microwaves). Total radiant energy depends on more than just the frequency. Radiant energy exhibits wave behaviors including reflection, refraction, absorption, superposition and diffraction. For opaque objects (e.g., paper, a chair, an apple), little if any radiant energy is transmitted into the new material. However, the radiant energy can be absorbed, usually increasing the thermal energy of the object and/or the radiant energy can be reflected. For rough objects, the reflection in all directions forms a diffuse reflection and for smooth shiny objects, reflections can result in clear images. Transparent materials transmit most of the energy through the material, but smaller amounts of energy may be absorbed or reflected.

Changes in the observed frequency and wavelength of a wave can occur if the wave source and the observer are moving relative to each other. When the source and the observer are moving toward each other, the wavelength is shorter and the observed frequency is higher; when the source and the observer are moving away from each other, the wavelength is longer and the observed frequency is lower. This phenomenon is called the Doppler shift and can be illustrated by listening to an ambulance siren as it travels past. As discussed in the Universe section of this course, this phenomenon is important to current understanding of how the universe is expanding. As a result, the light we receive from distant galaxies has a noticeable shift toward redder wavelengths (the so-called "redshift"). Calculations to measure the apparent change in frequency or wavelength are not appropriate for this course.

PS.EW.4: Thermal energy
In middle school, thermal energy is introduced as the energy of movement of the particles that make up matter. Processes of heat transfer, including conduction, convection and radiation, were studied. In other sections of this course, the role of thermal energy during heating, cooling and phase changes is explored conceptually and graphically. In this course, rates of thermal energy transfer and thermal equilibrium are introduced. Thermal conductivity depends on the rate at which thermal energy is transferred from one end of a material to another. Thermal conductors have a high rate of thermal energy transfer and thermal insulators have a slow rate of thermal energy transfer. The rate at which thermal radiation is absorbed or emitted by a system depends on its temperature, color, texture and exposed surface area. All other things being equal, in a given amount of time, black rough surfaces absorb more thermal energy than smooth white surfaces. An object or system is continuously absorbing and emitting thermal radiation. If the object or system absorbs more thermal energy than it emits and there is no change in phase, the temperature increases. If the object or system emits more thermal energy than is absorbed and there is no change in phase, the temperature decreases. For an object or system in thermal equilibrium, the amount of thermal energy absorbed is equal to the amount of thermal energy emitted; therefore, the temperature remains constant. In Chemistry, changes in thermal energy will be quantified for substances that change their temperature.

PS.EW.5: Electricity

In earlier grades, concepts of electrical conductors and insulators were introduced. A complete loop is needed for an electrical circuit that may be in parallel or in series. In this course, current, voltage and resistance are introduced conceptually to explain what was observed in middle school. The differences between electrical conductors and insulators can be explained by how freely the electrons flow throughout the material due to how firmly electrons are held by the nucleus. By convention, electric current is the rate at which positive charge flows in a circuit. In reality, it is the negatively charged electrons that are actually moving. Current is measured in amperes (A). An ampere is equal to one coulomb of charge per second (C/s). In an electric circuit, the power source supplies the electrons already in the circuit with electric potential energy by doing work to separate opposite charges. For a battery, the energy is provided by a chemical reaction that separates charges on the positive and negative sides of the battery. This separation of charge is what causes the electrons to flow in the circuit. These electrons then transfer energy to other objects and transform electrical energy into other forms (e.g., light, sound, heat) in the resistors. Current continues to flow even after the electrons transfer their energy. Resistors oppose the rate of charge flow in the circuit. The potential difference or voltage across an energy source is a measure of potential energy in joules supplied to each coulomb of charge. The volt (V) is the unit of potential difference and is equal to one joule of energy per coulomb of charge (J/C). Potential difference across the circuit is a property of the energy source and does not depend upon the devices in the circuit. These concepts can be used to explain why current will increase as the potential difference increases and as the resistance decreases. Experiments, investigations and testing (3-D or virtual) are used to construct a variety of circuits and to measure and compare the potential difference (voltage) and current. Circuits are dealt with conceptually in this course. Calculations are reserved for Physics.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PS.EW.1: Conservation of energy			
	Devise a procedure to calculate the speed of an object at constant velocity using a meter stick and a stopwatch or a frame-by-frame motion video. Use measured speed and mass to calculate kinetic energy.		Calculate potential energy given an object's mass and its height above a reference point. Calculate the kinetic energy of a moving object given the mass and velocity. Calculate the drop heights of objects based on their velocity at impact. Explain how the gravitational potential energy of an object varies based on the position of the reference point. Use the principle of conservation of energy to solve for an unknown quantity in a problem (e.g., beginning gravitational potential energy equals final kinetic energy for a falling object).
PS.EW.2: Transfer and transformation of energy (including work)			
	Design and conduct an investigation to estimate the energy lost (dissipated) in each bounce of a bouncing ball.	Use data to explain energy transformations occurring in a closed system.	Calculate the amount of work done by a force applied to an object. Calculate the amount of work transferred into or out of a system using changes in energy.
Awesome roller coaster design			
Design and build a roller coaster with at least two loops and one hill. Use the roller coaster to calculate kinetic and potential energy and identify the quantity of energy transferred out of the system during the ride. Then engineer a new design that would decrease the energy loss from the system.	Design a method to estimate the energy transferred to the surrounding environment as thermal energy through work done by frictional forces.	Label the rollercoaster to identify places where energy is converted from one type to another (e.g., where kinetic energy is being converted into gravitational potential energy). Explain how the gravitational potential energy of an object varies based on the position of the reference point.	Calculate the velocity at the bottom and top of each hill based on conservation of energy. Measure the velocity of the object at the bottom of each hill. Compare the measured velocity to the calculated velocity.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PS.EW.3: Waves			
Design an experiment to investigate radiant energy transmission, absorption, and reflection with a variety of materials (e.g., opaque, transparent, rough, smooth). Investigate the relationship between speed, frequency and wavelength for a transverse wave traveling through a Slinky®. Make claims about what happens to the speed and the wavelength of the wave as the frequency is increased and give evidence to support any claims. For example, use information from the investigation to explore the implications of cell phone usage. Include beneficial and harmful aspects of the use of this technology.	Construct a model to compare mechanical waves and electromagnetic waves. Research an observable wave phenomenon and design a demonstration to present to the class.	Give examples and illustrate wave behaviors including reflection, refraction, absorption, diffraction, and superposition. Identify the placement of each type of wave (e.g., gamma, x-ray, ultraviolet, visible, infrared, micro, radio) along the electromagnetic spectrum. Compare the relative wave energy, frequency and wavelength of different regions of the electromagnetic spectrum. Describe how the Doppler shift effect can produce a change in frequency for sound waves. Explain how sound or radiant waves are used in medicine or everyday life applications (e.g., ultrasound, lasers, x-rays).	Design an experiment to investigate radiant energy transmission, absorption, and reflection with a variety of materials (e.g., opaque, transparent, rough, smooth).
PS.EW.4: Thermal Energy			
Design a "cooler" cooler			
Use thermal conductivity concepts to improve a cooler design to keep beverages cold. Improve the design of the cooler to further reduce the transfer of thermal energy.	Design a method to investigate the thermal conductivity of potential materials to be used in the design.	Graphically compare potential materials based on the results of the investigations.	Differentiate between a thermal insulator and a thermal conductor. Provide examples of each.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PS.EW.5 - Electricity			
Given several circuit boards where current does not flow, determine why the current is not flowing and implement a solution to resolve the problem. Design a circuit that produces the maximum amount of light from a given set of materials (e.g., light bulbs, LEDs, various lengths of wires, batteries).	Design an investigation to determine the relationship between potential difference and current through a resistor.	Illustrate electric flow in parallel and series circuits. Explain situations where each type of circuit is more advantageous. Explain how resistance is an important concept in an engineering design context (e.g., determining how many light fixtures a circuit can handle, understanding how lack of insulation can cause short circuits).	Differentiate how electrons move in an insulator vs. a conductor. Compare the flow of electrons in a circuit to the flow of electrical energy. Analyze a circuit or schematic, to determine if it is a series or parallel circuit. Define and measure current, voltage and resistance. Explain that cells are joined together to form a battery. Explain conceptually how batteries generate electric current.
Design an electrically powered alarm system.			
Design an alarm system that uses a change in a circuit to indicate that the alarm has been triggered, (e.g., a short circuit changing current flow through a branch, a branch of a circuit opening to cease current flow).		Explain how the system sets off the alarm in terms of changes in current or potential difference in the circuit.	

Physical Science continued

PS.FM: FORCES AND MOTION
PS.FM.1: Motion

- Introduction to one-dimensional vectors
- Displacement, velocity (constant, average and instantaneous) and acceleration
- Interpreting position vs. time and velocity vs. time graphs

PS.FM.2: Forces

- Force diagrams
- Types of forces (gravity, friction, normal, tension)
- Field model for forces at a distance

PS.FM.3: Dynamics (how forces affect motion)

- Objects at rest
- Objects moving with constant velocity
- Accelerating objects

CONTENT ELABORATION: FORCES AND MOTION

Building upon content in elementary and middle school, major concepts of motion and forces are further developed. In middle school, speed was addressed conceptually, mathematically and graphically. The concepts that forces have both magnitude and direction and can be represented with force diagrams, that forces can be added to find a net force and that forces may affect motion have been addressed in middle school. At the high school level, mathematics (including graphing) is used when describing these phenomena, moving from qualitative understanding to one that is more quantitative. For this course, motion is limited to segments of uniform motion (e.g., at rest, constant velocity, constant acceleration) in a straight line either horizontally, vertically, up an incline or down an incline. Motions of two objects may be compared or addressed simultaneously (e.g., when or where would they meet).

PS.FM.1: Motion
The motion of an object depends on the observer's frame of reference and is described in terms of distance, position, displacement, speed, velocity, acceleration and time. Position, displacement, velocity and acceleration are all vector properties (magnitude and direction). All motion is relative to whatever frame of reference is chosen for there is no motionless frame from which to judge all motion. The relative nature of motion will be addressed conceptually, not mathematically. Non-inertial reference frames are excluded. Motion diagrams can be drawn and interpreted to represent the position and velocity of an object. Showing acceleration on motion diagrams is reserved for Physics.

The displacement or change in position of an object is a vector quantity that can be calculated by subtracting the initial position from the final position ($\Delta x = x_f - x_i$). Displacement can be positive or negative depending upon the direction of motion. Displacement is not always equal to the distance travelled. Examples should be given where the distance is not the same as the displacement.

Velocity is a vector quantity that represents the rate at which position changes. Average velocity can be calculated by dividing displacement (change in position) by the elapsed time ($v_{avg} = (x_f - x_i)/(t_f - t_i)$). Velocity may be positive or negative depending upon the direction of motion. Velocity should be distinguished from speed, which is always positive. Provide examples of when the average speed is not the same as the average velocity. Objects that move with constant velocity have the same displacement for each successive time interval. While speeding up or slowing down and/or changing direction, the velocity of an object changes continuously, from instant to instant. The speed of an object at any instant (clock reading) is called instantaneous speed.

Acceleration is a vector quantity that represents the rate at which velocity changes. Average acceleration can be calculated by dividing the change in velocity by elapsed time
($a_{avg} = (v_f - v_i)/(t_f - t_i)$). At this grade level, it should be noted that acceleration can be positive or negative, but specifics about what kind of motions produce positive or negative accelerations will be addressed in Physics. Deceleration is an ambiguous term that should only be used when an object is slowing down. Care should

be given to ensure students do not associate negative acceleration with only deceleration. Objects with negative acceleration could be increasing their speed. Objects that have no acceleration can either be standing still or be moving with constant velocity (speed and direction). Constant acceleration occurs when the change in an object's instantaneous velocity is the same for equal successive time intervals. Motion can be represented by position vs. time and velocity vs. time graphs. Specifics about the speed, direction and change in motion can be determined by interpreting such graphs. For this course, graphs will be limited to positive x-values and show only uniform motion involving segments of constant velocity or constant acceleration. Motion can be investigated by collecting and analyzing data in the laboratory and should include constant velocity as well as constant acceleration. Technology can enhance motion exploration and investigation through video analysis, the use of motion detectors and graphing data for analysis.

Objects that move with constant velocity and have no acceleration form a straight line (not necessarily horizontal) on a position vs. time graph. Objects that are at rest will form a horizontal line on a position vs. time graph. Objects that are accelerating will show a curved line on a position vs. time graph. Velocity can be calculated by determining the slope of a position vs. time graph. Positive slopes on position vs. time graphs indicate motion in a positive direction. Negative slopes on position vs. time graphs indicate motion in a negative direction. While it is important that students can construct graphs by hand, computer graphing programs or graphing calculators can also be used so more time can be spent on graph interpretation and analysis. Constant acceleration is represented by a straight line (not necessarily horizontal) on a velocity vs. time graph. Objects that have no acceleration (at rest or moving at a constant velocity) will have a horizontal line for a velocity vs. time graph. Average acceleration can be determined from the slope of a velocity vs. time graph. The details about motion graphs should not be taught as rules to memorize, but rather as generalizations that can be developed from interpreting the graphs.

PS.FM.2: Forces
Force is a vector quantity, having both magnitude and direction. Force diagrams are useful tools for visualizing and analyzing the forces acting on objects. The (SI) unit of force is a newton. One newton of net force will cause a 1 kg object to experience an acceleration of 1 m/s^2. A newton can also be represented as $kg{\cdot}m/s^2$. The opportunity to measure force in the lab is provided (e.g., with a spring scale or a force probe). Normal forces and tension forces are introduced conceptually at this level. These forces and other forces introduced in prior grades (friction, drag, gravitational, electric and magnetic) can be used as examples of forces that affect motion.

In this course, only forces in one dimension (positive and negative) will be addressed. The net force can be determined by one-dimensional vector addition. Gravitational force (weight) can be calculated from mass, but all other forces will only be quantified from force diagrams. Friction is a force that opposes motion. Kinetic friction (e.g., sliding, rolling), drag and static friction can be addressed conceptually. More quantitative study of friction forces, universal gravitational forces, elastic forces and electrical forces is reserved for Physics.

A normal force exists between two solid objects when their surfaces are pressed together due to other forces acting on one or both objects (e.g., a solid sitting on or sliding across a table, a ladder leaning against a wall, a ball hitting a bat). A normal force is always a push directed at right angles from the surfaces of the interacting objects. A tension force occurs when a non-slack rope, wire, cord or similar device pulls on another object.

In middle school, the concept of a field as a region of space that surrounds objects with the appropriate property (mass for gravitational fields, charge for electric fields, a magnetic object for magnetic fields) was introduced to explain gravitational, magnetic and electrical forces that occur over a distance. In high school, the field concept is further developed. The stronger the field, the greater the force exerted on objects placed in the field. The field of an object is always there even if the object is not interacting with anything else. The gravitational force (weight) of an object is proportional to its mass. Weight, F_g, can be calculated from the equation $F_g = mg$, where g is the gravitational field strength of an object which is equal to 9.8 N/kg or 9.8 m/s^2 on the surface of Earth.

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

An object will accelerate (increase or decrease its speed or change its direction of motion) when an unbalanced net force acts on it. The rate at which an object changes its speed or direction (acceleration) is proportional to the vector sum of the forces (net force, F_{net}) and inversely proportional to the mass ($a = F_{net}/m$).

These laws will be applied to systems consisting of a single object upon which multiple forces act. Vector addition will be limited to one dimension (positive and negative). While both horizontal and vertical forces can be acting on an object simultaneously, for this level, one of the dimensions must have a net force of zero.

A force is an interaction between two objects. Both objects in the interaction experience an equal amount of force, but in opposite directions. Interacting force pairs are often confused with balanced forces. Interacting force pairs can never cancel each other out because they always act on different objects. Naming the force (e.g., gravity, friction) does not identify the two objects involved in the interacting force pair. Objects involved in an interacting force pair can be easily identified by using the format "A acts on B so B acts on A." For example, the truck hits the sign therefore the sign hits the truck with an equal force in the opposite direction. Earth pulls the book down so the book pulls Earth up with an equal force. In Physics, all laws will be applied to systems of many objects.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		PS.FM.1: Motion	
	Conduct an investigation to determine the acceleration of a freely falling object.	Given real-world examples, explain how the frame of reference of an observer affects the appearance of motion. Create a velocity vs. time graph for an object using data from its position vs. time graph. Write a story describing an object's motion that corresponds to a velocity vs. time graph.	Identify examples of data that are vector quantities and examples of data that are scalar quantities. Determine the displacement of an object in one dimension, as measured from a frame of reference. Describe how an object can have a distance that is not the same as the displacement. Distinguish average velocity from instantaneous velocity. Calculate the velocity of an object by measuring the time to travel different distances and determine if the object moves with constant or changing velocity. Calculate the acceleration of an object from its change in speed during a given time interval. On a velocity vs. time graph, identify when an object is showing no motion, constant velocity and constant acceleration. Given a position vs. time graph, velocity vs. time graph, or acceleration vs. time graph identify the other corresponding graphs.
		Speed detection device	
Build a model of a device that could be used to determine the speed of a car travelling down the street.	Design a system or method to collect the data needed to calculate the speed of a car travelling down the street.	Present to the class how data will be measured and how it will be used to determine the speed of the car.	Decide what data must be collected to determine the speed of a car.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		Accelerating objects	
	Design a procedure to accurately measure the acceleration of a cart rolling down a ramp from rest. Collect data necessary to investigate the relationship between position and time for the cart. Analyze the data to determine the acceleration of the cart. Use this value to determine the speed of the cart at the end of the ramp. Measure the velocity of the cart at the end of the ramp (e.g., motion sensor) and compare it to the value calculated from the experimental data.	Make a claim about the relationship between position and time for an accelerating object and use evidence to support the claim. Present the findings to the class.	Calculate the final velocity of an object from the measured acceleration. Use motion sensors to determine speed and acceleration of objects.
		Motion of two objects	
Investigate how knowledge of the intersection point for two moving objects is used for controlling traffic patterns (e.g., air traffic control, trains).	Design a procedure to investigate the motion of two objects with different constant speeds (e.g., battery operated cars). Predict where two objects will cross paths when released at different times.	Produce position vs. time graphs and motion diagrams for two moving objects.	Determine the speed of two moving objects using their position vs. time graphs.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PS.FM.2: Forces			
	Determine the relationship between weight of an object in newtons (measured with a spring scale) and mass of an object in kilograms. Graph data for a variety of objects and interpret the graph to determine the gravitational field strength at the location where the measurements were taken.	Investigate the relationship between the frictional force on an object and the normal force between the object and the surface.	Solve problems determining the acceleration of an object from a force diagram. Identify the forces acting on various objects (e.g., a skydiver, a hanging mass, a chair resting on the floor) and draw force diagrams for the objects. Use a force diagram to predict the motion of an object. Calculate the weight of an object from its mass. Identify the relationship between gravitational field strength and the magnitude of the force on an object placed in the field. Compare the weight of objects on Earth to the predicted weights on other planets in our Solar System using the planets' gravitational field strength.
Rube Goldberg machine			
Design a Rube Goldberg machine that completes a task, (e.g., makes a fidget spinner spin, pops a balloon). Explain energy transfers in the machine caused by the force of gravity, friction, tension and normal forces.		Draw force diagrams for an object in the Rube Goldberg machine that is in equilibrium and for an object that is accelerating.	Identify the forces present throughout the Rube Goldberg machine. Calculate the forces involved in one energy transfer in the machine.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PS.FM.3: Dynamics (how forces affect motion)			
	Design an investigation to show the importance of seatbelt use. Create a persuasive public message (e.g., poster, television commercial, PSA, jingle or rap) including artifacts from the investigation to support the message. Focus on the forces and accelerations that a person would experience when wearing or not wearing a seat belt.	Provide an example of an object in equilibrium and determine the forces that are acting on the object. Create a force diagram of that object labeling the identified forces.	
Protective packaging			
Design and test methods that decrease the force on an object (e.g., egg, cell phone) so that it will survive being dropped from a given height. The focus should be on reducing the magnitude of the forces that the object will experience. Redesign and retest the methods based on initial testing.	Determine and carry out a procedure to measure the amount of force necessary to break an object (e.g., egg, cell phone screen). **Note:** *Use inoperative cell phones and observe proper safety protocols.*	Describe the amount of force needed to break an object (e.g., egg, cell phone screen). Use data collected to support the claim. Include any assumptions made.	

Physical Science continued

PS.U: THE UNIVERSE

PS.U.1: History of the universe

PS.U.2: Galaxies

PS.U.3: Stars

- Formation; stages of evolution
- Fusion in stars

CONTENT ELABORATION: THE UNIVERSE

In early elementary school, observations of the sky and space are the foundation for developing a deeper knowledge of the solar system. In late elementary school, the parts of the solar system are introduced, including characteristics of the sun and planets, orbits and celestial bodies. At the middle school level, energy, waves, gravity and density are emphasized in the physical sciences, and characteristics and patterns within the solar system are explored. In this course, the universe and galaxies are introduced, building upon the knowledge about space and the solar system from earlier grades.

PS.U.1: History of the Universe
The big bang model is a broadly accepted theory for the origin and evolution of our universe. It postulates that 12 to 14 billion years ago, the portion of the universe seen today was only a few millimeters across (NASA). According to the "big bang" theory, the contents of the known universe expanded explosively into existence from a hot, dense state 13.7 billion years ago (NAEP, 2009). After the big bang, the universe expanded quickly (and continues to expand) and then cooled down enough for atoms to form. Gravity pulled the atoms together into gas clouds that eventually became stars, which comprise young galaxies. Foundations for the big bang model can be included to introduce the supporting evidence for the expansion of the known universe (e.g., Hubble's law and red shift or cosmic microwave background radiation). A discussion of Hubble's law and red shift is found in the Galaxies section, below. Technology provides the basis for many new discoveries related to space and the universe. Visual, radio and x-ray telescopes collect information from across the entire electromagnetic spectrum; computers are used to manage data and complicated computations; space probes send back data and materials from remote parts of the solar system; and accelerators provide subatomic particle energies that simulate conditions in the stars and in the early history of the universe before stars formed.

PS.U.2: Galaxies
A galaxy is a group of billions of individual stars, star systems, star clusters, dust and gas bound together by gravity. There are billions of galaxies in the universe (NAEP 2009, page 52), and they are classified by size and shape. Most observed galaxies are classified as elliptical, spiral and irregular. The Milky Way is a spiral galaxy. It has more than 100 billion stars and a diameter of more than 100,000 light years. At the center of the Milky Way is a massive black hole around which is a collection of stars bulging outward from the disk, from which extend spiral arms of gas, dust and most of the young stars. The solar system is part of the Milky Way galaxy. Hubble's law states that galaxies that are farther away have a greater red shift, so the speed at which a galaxy is moving away is proportional to its distance from Earth. Red shift is a phenomenon due to Doppler shifting, so the shift of light from a galaxy to the red end of the spectrum indicates that the galaxy and the observer are moving farther away from one another. Doppler shifting is also found in the Energy and Waves section of this course.

PS.U.3: Stars
Early in the formation of the universe, stars coalesced out of clouds of hydrogen and helium and clumped together by gravitational attraction into galaxies. When heated to a sufficiently high temperature by gravitational attraction, stars begin nuclear reactions, which convert matter to energy and fuse the lighter elements into heavier ones. All elements, except for hydrogen and some helium and lithium, originated from nuclear fusion reactions of stars.

Stars are classified by their color, size, luminosity and mass. A Hertzprung-Russell diagram can be used to estimate the sizes of stars and predict how stars will evolve. Most stars fall on the main sequence of the H-R diagram, a diagonal band running from the bright hot stars on the upper left to the dim cool stars on the lower right. Stars like the sun will eventually collapse to become a white dwarf, while more massive stars will collapse to form neutron stars or black holes. For stars like the sun, this process of collapse will produce a nebula. More massive stars will collapse with a supernova explosion. The gas ejected from the system during the end stages of the star's life may eventually coalesce under gravity to form new stars, and the stellar life cycle with begin again.

Note: *Names of stars and naming the evolutionary stage of a star from memory is not the focus. The emphasis is on the interpretation of data (using diagrams and charts) and the criteria and processes needed to make those determinations.*

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PS.U.1: History of the universe			
Create or improve a device to collect data from a portion of the universe, understanding that there are situations where we cannot directly observe or measure something in a straightforward way.	Analyze a plot of distance vs. redshift of galaxies to recognize the trend that more distant galaxies are moving away from our location faster. Design a model to show this phenomenon (e.g., drawing dots on a balloon and blowing it up, paperclips on a stretching rubber band).	Use a 12-month calendar to construct a "Cosmic Calendar" to depict the 14-billion-year history of the universe. Explain the "raisin cake" analogy for the expansion of the universe and how it makes sense of the observed relationship between distance and redshift of nearby galaxies. Investigate features of a solid planetary body using the *WorldWide Telescope*. Identify features that are oldest vs. those that are youngest and draw conclusions about the reasons for the differences using current theory to support the conclusions.	Explain that the universe had a beginning in the distant past; the universe is not infinitely old. Provide evidence that the universe is expanding.
PS.U.2: Galaxies			
Research the Hubble space telescope from an engineering perspective. What were the problems encountered by this mission and how they were solved? How was the telescope upgraded over time? What scientific knowledge was gained from these technological improvements and fixes? What future improvements to the Hubble telescope would you make?[1] Evaluate data analyzing the penetration ability of gamma radiation, X-rays, UV, visible light, infrared and radio wavelengths in Earth's atmosphere. Based on the analysis and pertinent considerations (e.g., certain wavelengths of light are blocked from reaching Earth's surface by the atmosphere, how efficiently telescopes work at different		Use real-time data from the NASA Hubble Mission to research and document the history of the mission, marking the time, discoveries and impact to humans. Present a final product (e.g., an e-portfolio, presentation, formal poster session).	Identify three galaxy types: elliptical, spiral and irregular. Identify the Milky Way as a spiral galaxy. Recognize that our solar system is part of the Milky Way Galaxy. Explain that galaxies formed in the early universe when gravity caused gas clouds to collapse to form stars. Explain how we are able to see galaxies.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
wavelengths, telescopes in space are much more expensive to construct than Earth-based telescopes) recommend to a federal funding agency which telescope project should receive funds for construction. The two projects to consider are: • Project 1 – A UV wavelength telescope, placed high atop Mauna Kea in Hawaii at 14,000 ft. above sea level, which will be used to look at distant galaxies. • Project 2 – A visible wavelength telescope, placed on a satellite in orbit around Earth, which will be used to observe a pair of binary stars located in the constellation Ursa Major (Big Dipper). (Prather, Slater, Adams, & Brissenden, 2008)			

[1]Hubble servicing information

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PS.U.3: Stars			
Design a pinhole camera and refine it to project an image of the sun that has a good balance between brightness and resolution. Relate the size of the hole to brightness and resolution.		Explain how gravity wave detection confirmed the existence of black holes. A gravity wave signal was detected in 2015 from two black holes that collided and merged together without creating a huge explosion because the light produced by this event got sucked into the resulting black hole. This could not have happened if the two objects had been stars. Use a Hertzsprung-Russell diagram to predict the evolution of stars (e.g., how long the star will last, what it will become after it runs out of fuel). Choose a star or star system and draw a sunset from the perspective of a planet that is in the "habitable zone" for that star(s). Research how computer simulations are used to model the formation of stars. Observe star formation and end states. Document observations. A nearby gas cloud where stars are forming is the Orion nebula which is easy to see with a telescope or binoculars. The bright stars at the center of the nebula are recently formed and illuminate the surrounding gas and dust. The Crab nebula is an example of the end state of a star that is easy to see with a telescope or binoculars.	Explain how stars form. Describe the stages of our sun and compare them to those of more and less massive stars. Explain how stars can end up as white dwarfs, neutron stars and black holes. Compare the sizes of these end products. Explain fusion reactions in stars and how they are different from chemical reactions. Describe how the plasma phase differs from the other phases of matter.

Biology

INTRODUCTION AND SYLLABUS

COURSE DESCRIPTION

Biology is a high school level course, which satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires three units of science.. Each course should include inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.

This course investigates the composition, diversity, complexity and interconnectedness of life on Earth. Fundamental concepts of heredity and evolution provide a framework through inquiry-based instruction to explore the living world, the physical environment and the interactions within and between them.

Students engage in investigations to understand and explain the behavior of living things in a variety of scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications.

COURSE CONTENT

The following information may be taught in any order; there is no ODE-recommended sequence.

B.H: HEREDITY

- **B.H.1:** Cellular genetics
- **B.H.2:** Structure and function of DNA in cells
- **B.H.3:** Genetic mechanisms and inheritance
- **B.H.4:** Mutations
- **B.H.5:** Modern genetics

B.E: EVOLUTION

- **B.E.1:** Mechanisms
  - Natural selection
  - Mutation
  - Genetic drift
  - Gene flow (immigration, emigration)
  - Sexual selection
- **B.E.2:** Speciation
  - Biological classification expanded to molecular evidence
  - Variation of organisms within species due to population genetics and gene frequency

B.DI: DIVERSITY AND INTERDEPENDENCE OF LIFE

- **B.DI.1:** Biodiversity
  - Genetic diversity
  - Species diversity
- **B.DI.2:** Ecosystems
  - Equilibrium and disequilibrium
  - Carrying capacity
- **B.DI.3:** Loss of Diversity
  - Climate change
  - Anthropocene effects
  - Extinction
  - Invasive species

B.C: CELLS

- **B.C.1:** Cell structure and function
  - Structure, function and interrelatedness of cell organelles
  - Eukaryotic cells and prokaryotic cells
- **B.C.2:** Cellular processes
  - Characteristics of life regulated by cellular processes
  - Photosynthesis, chemosynthesis, cellular respiration, biosynthesis of macromolecules

NATURE OF SCIENCE HIGH SCHOOL

Nature of Science
One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.

Categories	High School
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Identify questions and concepts that guide scientific investigations. • Design and conduct scientific investigations using a variety of methods and tools to collect empirical evidence, observing appropriate safety techniques. • Use technology and mathematics to improve investigations and communications. • Formulate and revise explanations and models using logic and scientific evidence (critical thinking). • Recognize and analyze explanations and models. • Communicate and support scientific arguments.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	• Various science disciplines use diverse methods to obtain evidence and do not always use the same set of procedures to obtain and analyze data (i.e., there is no one scientific method). o Make observations and look for patterns. o Determine relevant independent variables affecting observed patterns. o Manipulate an independent variable to affect a dependent variable. o Conduct an experiment with controlled variables based on a question or hypothesis. o Analyze data graphically and mathematically. • Science disciplines share common rules of evidence used to evaluate explanations about natural phenomenon by using empirical standards, logical arguments and peer reviews. o Empirical standards include objectivity, reproducibility, and honest and ethical reporting of findings. o Logical arguments should be evaluated with open-mindedness, objectivity and skepticism. • Science arguments are strengthened by multiple lines of evidence supporting a single explanation. • The various scientific disciplines have practices, methods, and modes of thinking that are used in the process of developing new science knowledge and critiquing existing knowledge.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• Science depends on curiosity, imagination, creativity and persistence. • Individuals from different social, cultural, and ethnic backgrounds work as scientists and engineers. • Science and engineering are influenced by technological advances and society; technological advances and society are influenced by science and engineering. • Science and technology might raise ethical, social and cultural issues for which science, by itself, does not provide answers and solutions.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• Science can advance through critical thinking about existing evidence. • Science includes the process of comparing patterns of evidence with current theory. • Some science knowledge pertains to probabilities or tendencies. • Science should carefully consider and evaluate anomalies (persistent outliers) in data and evidence. • Improvements in technology allow us to gather new scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Biology continued

B.H: HEREDITY
B.H.1: Cellular genetics
B.H.2: Structure and function of DNA in cells
B.H.3: Genetic mechanisms and inheritance
B.H.4: Mutations
B.H.5: Modern genetics

CONTENT ELABORATION: HEREDITY

Building on knowledge from elementary school (plants and animals have life cycles and offspring resemble their parents) and knowledge from middle school (reproduction, Mendelian genetics, inherited traits and diversity of species), Heredity focuses on the explanation of genetic patterns of inheritance. In middle school, students learn that living things are a result of one or two parents, and traits are passed to the next generation through either asexual or sexual reproduction. Foundational concepts of mitosis and meiosis are introduced in grades 6 and 8. In addition, they learned that traits are defined by instructions encoded in many discrete genes and that a gene may come in more than one form called alleles.

B.H.1: Cellular genetics
Life is specified by genomes. Each organism has a genome that contains all the biological information needed to develop and maintain that organism. The biological information contained in a genome is encoded in its deoxyribonucleic acid (DNA) and is divided into discrete units called genes. Genes code for proteins. Different parts of the genetic instructions are used in different types of cells, influenced by the cell's environment and history. The many body cells in an individual can be very different from one another, even though they are all descended from a single cell and thus have essentially identical genetic instructions. (AAAS)

B.H.2: Structure and function of DNA in cells
Mendel's laws of inheritance (introduced in grade 8) are interwoven with current knowledge of DNA and chromosome structure and function to build toward basic knowledge of modern genetics. Genes are segments of DNA molecules. The sequence of DNA bases in a chromosome determines the sequence of amino acids in a protein. Inserting, deleting or substituting segments of DNA molecules can alter genes. Sorting and recombination of genes in sexual reproduction and meiosis specifically result in a variance in traits of the offspring of any two parents. This content can be explicitly connected to evolution.

B.H.3: Genetic mechanisms and inheritance
Genetic variation in traits among offspring is a result of the movement of chromosomes crossing over, independent assortment, and recombination during gamete formation. Gene interactions described in middle school were limited primarily to dominant and codominant traits. In high school, genetic mechanisms, both classical and modern, including incomplete dominance, sex-linked traits, and dihybrid crosses, are investigated through real-world examples. Statistics and probability allow us to compare observations made in the real world with predicted outcomes. Dihybrid crosses can be used to explore linkage groups, gene interactions and phenotypic variations. Chromosome maps reveal linkage groups.

B.H.4: Mutations
Genes can be altered by insertion, deletion, or substitution of a segment of DNA molecules. An altered gene is a mutation and will be passed on to every cell that develops from it. The resulting features may help, harm or have little or no effect on the offspring's success in its environments. Gene mutations in gametes are passed on to offspring.

B.H.5: Modern genetics
Technological developments that lead to the current knowledge of heredity are introduced for study. The development of the model for DNA structure was the result of experimentation, hypothesis, testing, statistical analysis and technology as well as the studies and ideas of many scientists. James Watson and Francis Crick developed the current model based on the work of Rosalind Franklin and others. Scientists continue to extend the model and use it to devise technologies to

further our understanding and application of genetics. The emphasis is not on the memorization of specific steps of gene technologies, but rather on the interpretation and application of the results.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.H.1: Cellular genetics			
Discuss ways that human genetic information can be used (e.g., ancestry, health) and the ethical implications of using this information.		Using information from the Human Genome Project, show how DNA testing companies have developed and what information is used to show how people are related. Compare the DNA sequences of different cells from the same organism. Explain how all cells, except gametes, in a specific organism have identical genetic information (DNA) but have different functions. Compare the information that is provided by various commercial genetic testing companies and determine how it can be used.	Describe the central dogma (DNA to RNA to protein) and its relationship to heredity.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.H.2: Structure and function of DNA in cells			
		Discuss and provide evidence that phenotypic variations may result from genetic recombination through meiosis (e.g., sorting, recombination, crossing over) and sexual reproduction.	Given one strand of DNA, construct the complementary strand and/or the mRNA molecule transcribed from it. Describe the process of meiosis in relation to the function of DNA and chromosomes in coding the instructions for traits passed from parents to offspring.
B.H.3: Genetic mechanisms and inheritance			
	Propose hypotheses, design experiments and analyze a population (e.g., dog breeds, fruit flies, Fast Plants, virtual simulations) to identify the genotypes of one or more individuals with unknown genotypes. Use Punnett Squares and pedigrees based on their phenotypes and the phenotypes of their offspring. Use the principles of statistics to compare real-world data to predicted outcomes.	Explain the outcomes of a series of genetic crosses from a population (e.g., fruit flies, virtual simulation, Fast Plants) using Mendelian and non-Mendelian genetics (e.g., incomplete dominance, sex-linked traits, dihybrid crosses). Include a discussion of gene interactions, gene linkage and the source of phenotypic variation.	Use a model of meiosis to demonstrate crossing over and independent assortment during gamete formation. Explain how this contributes to variation within a population.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.H.4: Mutations			
		Given examples of original and mutated DNA segments, analyze the mutation and identify the impact on phenotype. Make a connection to how natural selection might favor, select against or be neutral on the resulting changes in the protein (phenotype).	Recall types of mutations and describe the effects they might have on a protein. Classify mutations as gene mutations (e.g., insertion, deletion, substitution) or chromosomal mutations (e.g., trisomy, monosomy). Evaluate chromosome maps to identify linkage groups.
B.H.5: Modern genetics			
Research current genetic engineering practices (e.g., Clustered Regularly Interspaced Short Palindromic Repeats [CRISPR], GMO, specially modified bacteria, cloning, epigenetic technology). Evaluate the implications of implementing genetic engineering practices. Using knowledge of genetic technology, create a proposal for the design of a product to solve a current world problem (e.g., golden rice, oil-eating bacteria, insulin-producing bacteria, pigs for producing human organs).	Given a problem (e.g., diseases, hunger, pests, water concerns), propose a solution that uses genetic technology (e.g., specially modified bacteria, GMO, CRISPR, epigenetic technology) and defend your reasoning. Use electrophoresis (actual or virtual) technology to evaluate DNA results (e.g., crime scene analysis, paternity, phylogenetic relationships).	Explain how electrophoresis is used to evaluate DNA results (e.g., crime scene analysis, paternity, phylogenetic relationships).	Create a timeline of the significant discoveries in genetics.

Biology continued

B.E: EVOLUTION

B.E.1: Mechanisms

- Natural selection
- Mutation
- Genetic drift
- Gene flow (immigration, emigration)
- Sexual selection

B.E.2: Speciation

- Biological classification expanded to molecular evidence
- Variation of organisms within a species due to population genetics and gene frequency

CONTENT ELABORATION: EVOLUTION

The basic concept of biological evolution is that Earth's present-day species descended from earlier, common ancestral species. At the elementary school level, evolution concepts include the relationship between organisms and the environment, interactions among parents and offspring and an introduction to the fossil record and extinction. At the middle school level, concepts include biodiversity (as part of biomes) and speciation, further exploration of the fossil record and Earth's history, changing environmental conditions (abiotic factors), natural selection and biological evolution. At the high school level, the study of evolution includes Modern Synthesis, the unification of genetics and evolution, historical perspectives of evolutionary theory, gene flow, mutation, speciation, natural selection, genetic drift and sexual selection.

B.E.1: Mechanisms

Natural selection is used to describe the process by which traits become more or less common in a population due to consistent environmental pressures upon the survival and reproduction of individuals with the trait. Mathematical reasoning is applied to solve problems (e.g., use Hardy-Weinberg principle to explain deviations in observed gene frequency patterns in a population compared to expected patterns based on the assumptions of the principle). Populations evolve over time. Evolution through natural selection is the consequence of the interactions of:

1. The potential for a population to increase its numbers;
2. The genetic variability of offspring due to mutation and recombination of genes;
3. A finite supply of the resources required for life; and
4. The differential survival and reproduction of individuals based on phenotype(s).

Mutations are described in the content elaboration for Heredity. Apply the knowledge of mutation and genetic drift to real-world examples. Biological evolution explains the natural origins for the diversity of life. Emphasis shifts from thinking in terms of selection of individuals with a particular trait to changing proportions of a trait in populations as a result of the mechanisms of natural selection, genetic drift, movement of genes into and out of populations and sexual selection.

B.E.2: Speciation

Biological classification expanded to molecular evidence

Classification systems are frameworks, developed by scientists, for describing the diversity of organisms; indicating the degree of relatedness among organisms. Recent molecular sequence data generally support earlier hypotheses regarding lineages of organisms based upon morphological comparisons. Both morphological and molecular comparisons can be used to describe patterns of biodiversity (cladograms present hypotheses to explain descent from a common ancestor with modification). The concept of descent from a common ancestor with modification provides a natural explanation for the diversity of life on Earth as partially represented in the fossil record and in the similarities of existing species.

Variation of organisms within a species due to population genetics and gene frequency
Different phenotypes result from new combinations of existing genes or from mutations of genes in reproductive cells. At the high school level, the expectation is to combine grade 8 knowledge with an explanation of genes and the function of chromosomes. Natural selection works on the phenotype.

Heritable characteristics influence how likely an organism is to survive and reproduce in a particular environment. When an environment changes, the survival value of inherited characteristics may change. This may or may not cause a change in species that inhabit the environment. Use real-world examples to illustrate natural selection, gene flow, sexual selection, and genetic drift.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.E.1: Mechanisms			
Genetic drift			
Consider an organic farming operation growing a heritage variety of sweet corn. The operation borders a large, industrial farm producing genetically modified corn. The organic farm's success is threatened by both gene flow from the corporate GMO (genetically modified organism) farm and genetic drift. Propose a solution to minimize the effect of these factors on the organic farm. Design a solution to lessen the impact of genetic drift (e.g., increasing genetic variation in populations of cheetahs or lowland gorillas housed in zoos around the world).	Generate hypotheses to explain real-world examples of apparent genetic drift (e.g., maintaining heritage breeds of crop plants and livestock, hemophilia in Queen Victoria's descendants, polydactylism in the Amish population, inbreeding in isolates, island populations, loss of diversity in artificially fertilized livestock or zoo populations).	Identify and explain a real-world example of genetic drift.	Differentiate between gene flow (e.g., pollen from GM crops blowing to an organic farmer's crop) and genetic drift (e.g., limited variation within corn crops).

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Modeling Hardy Weinberg			
Critique a real-world solution to the arrival of an invasive species and how it changed native populations and/or the invasive population with respect to Hardy-Weinberg assumptions (e.g., Ohio examples: Japanese honeysuckle, zebra and quagga mussels, Emerald Ash Borers, purple loosestrife, white-nose syndrome in bats). Design an engineering or technical solution to keep out or remove an invasive species from a local habitat (e.g., invasive fish out of Lake Michigan, garlic mustard, Zebras mussels, invasive lampreys from Great Lakes tributaries). Construct a program to remove all descendants of invasive species in a habitat (e.g. rats on small Pacific island). Design an engineering/technical solution to help return native species following the intentional removal of all invasive species (e.g. rats on small Pacific islands). Design and construct a habitat that maintains the gene pool of a transplanted population at equilibrium.	Generate hypotheses to predict the ecological changes following the appearance of an invasive species into a new habitat (e.g., fire ants invading Ohio) based on reports of the impact of that species in other habitats in the recent past.	Using a model of Hardy Weinberg, explain the results of a change generated in the model population. Prepare a visual representation to present information. Identify the likely stakeholders (e.g., commercial or sporting groups) affected by the arrival of an invasive species. Prepare a presentation for those stakeholders about predicted changes and the basis for making these predictions.	Use Hardy-Weinberg principles to explain the concept of an individual acting as a "carrier" of a rare genetic disorder. Provide an example of an invasive species and describe the nature of the biological relationship with each native species that is impacted.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.E.2: Speciation			
Natural selection			
Design a medical protocol to discourage the persistence (spread) of antibiotic resistance through natural selection in populations of bacteria. Design an agricultural solution/procedure to discourage the persistence (spread) of herbicide resistance in crop plants or pesticide resistance in insects through natural selection.	For two closely related species such as sibling species, (e.g., tassel-eared squirrels, yellow-rumped and Audubon's warbler, plant examples) propose hypotheses to explain their current distributions.	Given information about the current range and population size of a species, predict the effect of a change in environmental factors (e.g., retreat of the last glaciers, rapid increase in water temperatures in the Gulf of Maine) on the species. Design a public exhibit that attracts tourists by demonstrating convergent evolution of plants on different continents. Compare the work of Lamarck, Darwin and Wallace.	Explain how natural selection has affected a species (e.g., Darwin's finches, peppered moths, Hawaiian honeycreepers, Galapagos tortoises).
Variance within and between populations			
Observe and measure traits within several groups of local species. Propose an engineering solution to block or allow interbreeding between neighboring populations (e.g., tassel-eared squirrels).	Examine neighboring populations of similar species. Propose one or more analyses to determine if they are distinct species.	Present graphically the distribution of a specific trait within and between species in a group (e.g., needle length or number of needles in multiple pine species). Interpret your data through natural selection.	Identify a geographical barrier likely responsible for distinct, yet similar populations in an area (e.g., Lake Erie Water Snakes (LEWS), tassel-eared squirrels) and explain how it might account for the close similarity of multiple forms.
Modern and historical theory			
		Explore modern and historical evidence from various disciplines (e.g., molecular, anatomical, paleontological) that support the theory of evolution through natural selection.	Use molecular, anatomical, and/or paleontological data to explain classic examples of convergent evolution.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Evolutionary relatedness			
Design a technological solution to determine identification in species where visual cues alone cannot determine the identity (e.g., bird species that can only be identified by their song or mating behaviors).	Select a group of organisms and generate an evolutionary hypothesis with a cladogram using researched data (e.g., molecular, anatomical, binomial nomenclature). Evaluate cladograms produced by classmates. Support proposed evolutionary relationships with evidence.	Interpret the degree of evolutionary relatedness (phylogenetic closeness) based on information found in a cladogram. Evaluate two or more cladograms representing different hypotheses of the evolution of a given clade.	Given data in a table (e.g., molecular, anatomical, binomial nomenclature) illustrate evolutionary relatedness (phylogenetic closeness) using a cladogram.

Biology continued

B.DI: DIVERSITY AND INTERDEPENDENCE OF LIFE
B.DI.1: Biodiversity

- Genetic diversity
- Species diversity

B.DI.2: Ecosystems

- Equilibrium and disequilibrium
- Carrying capacity

B.DI.3: Loss of diversity

- Climate change
- Anthropocene effects
- Extinction
- Invasive species

CONTENT ELABORATION: DIVERSITY AND INTERDEPENDENCE OF LIFE

Building on knowledge from elementary school (interactions of organisms within their environment and the law of conservation of matter and energy, food webs) and from middle school (flow of energy through organisms, biomes and biogeochemical cycles), this topic at the high school level focuses on the study of diversity and similarity at the molecular level of organisms. Additionally, the effects of physical/chemical constraints on all biological relationships and systems are investigated. The unidirectional flow of energy and the cycling of matter as organisms grow, reproduce and die occurs at all levels of biological organization. Previous knowledge focused on biological systems at equilibrium; at the high school level, biological systems not at equilibrium and their responses are considered. Diagrams and models are used to explain the effects of real-world interactions and events within an ecosystem.

B.DI.1: Biodiversity
The great diversity of organisms and ecological niches they occupy result from more than 3.8 billion years of evolution. Populations of individual species and groups of species comprise a vast reserve of genetic diversity. Loss of diversity alters energy flow, cycles of matter and persistence within biological communities. Loss of genetic diversity in a population increases its probability of extinction.

B.DI.2: Ecosystems
Ecosystems change as geological and biological conditions vary due to natural and anthropogenic factors. Like many complex systems, ecosystems have cyclical fluctuations around a state of equilibrium. The rate of these fluctuations in ecosystems can increase due to anthropogenic factors. Changes in ecosystems may lead to disequilibrium, which can be seen in variations in carrying capacities for many species. Authentic data are used to study the rate of change in matter and energy relationships, population dynamics, carbon and nitrogen cycling, population changes and growth within an ecosystem. Graphs, charts, histograms and algebraic thinking are used to explain concepts of carrying capacity of populations and homeostasis within ecosystems by investigating changes in populations that occur locally or regionally. Mathematical models can include the exponential growth model and the logistic growth model. The simplest version of the logistic growth model is Population Growth Rate = $rN(K-N)/K$, which incorporates the biological concept of limited (non-infinite) carrying capacity, based upon intra- and interspecies competition for resources such as food, as represented by the variable K. Carrying capacity is defined as the population equilibrium size when births and deaths are equal; hence Population Growth Rate = zero.

B.DI.3: Loss of diversity
An ecosystem will maintain equilibrium with small fluctuations in its abiotic and biotic components, but significant fluctuations can result in long-term alterations of the ecosystem and ultimately a loss of biodiversity. This can be caused by natural and anthropogenic events. Humans are a biotic factor in ecosystems and can impact critical variables within these systems. Climate is dependent on a number of feedback loops between sunlight, the ocean, the atmosphere and the biosphere. Increasing mean global temperatures cause increased variance in weather that impacts both biotic and abiotic factors. Multiple changes happening

simultaneously can stress ecosystems. Extreme events such as prolonged drought, floods, or the introduction or removal of species can result in long-term alterations to ecosystems and their functions. The current rate of extinction is at least 100-1000 times the average background rate observed in the fossil record. The observed rates of biodiversity loss are indicative of a severe and pervasive disequilibrium in ecosystems. At the high school level, students should examine the factors that contribute to the accelerated extinction rates observed today and the implications of declining biodiversity carrying capacity. Misconceptions about population growth capacity, interspecies and intraspecies competition for resources, and what occurs when members of a species immigrate to or emigrate from ecosystems are included in this topic. Technology can be used to access real-time/authentic data to study population changes and growth in specific locations.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

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B.DI.1: Biodiversity			
Genetic diversity			
Investigate a species of extremely low abundance (e.g., Vaquita porpoise, Sumatran/Javan rhinos or native bees) and propose monitoring or management methods to increase the genetic diversity.	Investigate various agricultural/crop production practices, then propose a hypothesis to explain how these practices might impact a species' genetic diversity. Review data (e.g., recorded by National Center for Biotechnology Information, National Institutes of Health, Centers for Disease Control and Prevention) to examine genetic diversity within populations. Evaluate populations with specific genetic traits and how these are related to the survival abilities of the population (e.g., Irish potato famine, northern white rhino, hemophilia, sickle cell anemia, malaria). Compare and contrast the factors that influence growing/propagating different varieties (e.g., heirloom and genetically modified organisms) of plants of the same species. This could include growing each variety if resources permit. Using this information, advise the stakeholders of a country/community about the trade-offs of growing each type of plant.	Use a model or simulation to analyze the impact of an environmental stressor on the genetic diversity and long-term survival of a population.	Identify organisms with high (e.g., tomatoes, beans) and low (e.g., cheetahs) genetic diversity. Recognize that species with low genetic diversity are more likely to become extinct.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Species diversity			
Propose and justify suggestions to increase diversity and stability of an ecosystem. Design, evaluate, and refine a solution to reduce the impacts of human activities on the environment and biodiversity. Investigate the practice of stocking fish in Ohio to identify potential problems and benefits of this practice. Examine how this practice impacts the environment. Develop a public service announcement (PSA) to inform the community about a specific fish that will be stocked in the community's local waterway. Explore a species that has been removed from the endangered species list (e.g., Lake Erie Water Snakes (LEWS), river otters, bobcats). Evaluate how this action can impact the species and the environment.	Investigate species diversity for local populations, which could include school grounds and/or local wildlife areas, by comparing the number of different species to the abundance of each species. Consider a stream survey or investigate the influence of introducing wolves back into an ecosystem (e.g., Isle Royale, Yellowstone).	Using data on a variety of Ohio species, create a chart comparing the species diversity across the state's ecosystems. Use historical and real-time data (e.g., Ohio Department of Natural Resources (ODNR) historical and current data) to monitor changes in populations of Ohio species and correlate population size to wildlife management policies (e.g., river otters, deer, Canada geese, sturgeons). Examine current lake or stream fish populations in local bodies of water to make predictions of future population numbers. Compare this to past years data from ODNR and project future population numbers. Investigate the species diversity within a biome. Analyze the number of different types of vertebrates, invertebrates and plant species in a biome. Identify patterns in distribution between different biomes and consider the influence latitude and/or altitude plays on species diversity. Correlate the patterns of diversity with energy flow, cycles of matter, and persistence within biological communities.	

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.DI.2: Ecosystems			
Equilibrium and disequilibrium			
Devise a plan to address the ecological and economic impacts of an invasive species. The plan should address lessening the species' impacts. Design, evaluate, and communicate to stakeholders the strategies to restore equilibrium to an ecosystem previously altered by human impact (e.g., dams, channelization, urbanization, nutrient overload/algal blooms in lakes). Select a species that has recently been removed from the endangered species list. Evaluate the current management plan and how this action will impact the species and the environment.	Devise a study to investigate an ecosystem in equilibrium and an ecosystem in disequilibrium (e.g., changing populations of algae species in an aquarium as a function of phosphorus concentration over time). Gather data and analyze the results.	Predict how predator/prey population cycles (e.g., moose/wolf, hare/lynx) will change if there are changes in the numbers of either species. Explain how humans can impact predator/prey relationships (e.g., hunting large predators such as wolves, hunting large herbivores such as bison, Nile Perch). Compare equilibrium and disequilibrium. Give examples of each in real populations. Relate this to Ohio animals and plants. Consider the impact of stocking fish on a native population of the same or similar (able to interbreed) fish (e.g., rainbow trout). Investigate an invasive species in Ohio (e.g., zebra mussels, purple loosestrife, emerald ash borer, sea lamprey, honeysuckle, gobies, Asian carp), analyze its impacts and predict the ecological and economic impacts on communities. Research should include analyzing the factors that contribute to the organism's success as well as various ideas to provide a solution for managing the species.	

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Carrying capacity			
	Investigate how urban sprawl affects carrying capacity for a native population (e.g., loss of native populations from the introduction of kudzu for groundcover, the use of Japanese honeysuckle for ornamentation).	Analyze population data for patterns in population cycles and determine carrying capacities. Identify and explain correlations between variables in population data. Track the effect of varying levels of disturbance (e.g., regulated hunting, poaching, seasonal flooding, volcanic eruption, sea level rise) on ecosystems and create data sets to communicate findings.	Identify and label various features of population growth curves (e.g., fast or slow growth rates, carrying capacity, equilibrium, population boom and bust). Describe the characteristics of exponential and logistical growth.
Population studies			
Design a tracking method to estimate population size and carrying capacity for an organism.	Use real-time data (e.g., from student designed tracking methods or Movebank data) to track and monitor populations. Analyze data to determine population cycles and carrying capacity.		

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.DI.3: Loss of diversity			
Climate change			
Heat retention due to increasing levels of atmospheric greenhouse gases poses challenges for species. Use data-driven models to predict how current rates of change could reshape the range and distribution of species.	Use satellite or buoy temperature data to analyze ocean temperature and evaluate temperature effects on marine life. Investigate a local species (e.g., tree, insect, amphibian, reptile). Use historical and current data to create a profile of the species showing the impact of climate over the past century. Conduct an experiment to measure changes in temperature of an enclosed environment (e.g., terrarium, 2L bottle) by altering variables such as light intensity, CO_2 and humidity. Compare the effect of different factors on the enclosed ecosystem. Plan a project utilizing real-time/authentic data (e.g., community planners, ODNR, interviews with local farmers) to explain strategies (e.g., pest control, water supply, crop rotations, stormwater management) used to adapt to changes in climate.	Given real-world data charts from NASA or NOAA construct graphs to examine how factors involved in climate change impact global biological diversity (e.g., coral reefs, desertification, ocean acidification). Compare historical levels of atmospheric greenhouse gases with levels over the last century. Relate this to climate change and its impact on biodiversity. Identify patterns in local weather conditions (e.g., temperature, precipitation) and changes in the severity or frequency of extreme weather events. Make inferences on how these changes may impact Ohio climate zones in the future.	Describe feedback loops that exist between sunlight, the ocean, the atmosphere and the biosphere. List examples of local environmental impacts caused by climate change (e.g., increased flooding, shoreline erosion, shifting planting zones, drought). Draw and label a biogeochemical cycle (e.g., carbon cycle, water cycle, nitrogen cycle). Identify the factors within this cycle that are influenced by climate change.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Anthropocene effects			
Design, evaluate, or refine a solution for reducing the impacts of human activities (e.g., urbanization, building dams, introduction of invasive species, sinking ships to rebuild coral reefs, creating manmade lakes) on the environment and biodiversity. Research how domestication and selective breeding have impacted animal and plant genetic biodiversity (e.g., apples, dogs). Analyze the impacts of the changes. Predict how biodiversity will be impacted in the future.	Design a study to examine how Earth system interactions are modified by human activities (e.g., an increase in atmospheric carbon dioxide results in an increase in ocean acidification that impacts marine populations).	Provide examples of GMOs and examine their possible impact on the environment. Use principles of evolution through natural selection to explain the rise in the occurrence of herbicide-resistant weeds in areas using herbicide-resistant GMO corn and soy seeds. Compare this process with the rise of antibiotic-resistant microbes.	Identify and describe anthropogenic factors (e.g., acid rain, ozone depletion, landfill leaching, thermal pollution, light pollution) and correlate these influences with their impacts on the environment. Graph the global growth of the human population over the last 10,000 years.
Extinction			
Research the role zoos are playing in the conservation of endangered or threatened species. Analyze the impact of these efforts to address the potential loss of diversity within the species or within the ecosystem. Identify the limitations of zoo-based captive breeding programs (e.g., inbreeding) and propose solutions to minimize such problems. Investigate a species of extremely low abundance (e.g., Vaquita porpoise, Sumatran/Javan rhinos) and propose monitoring or management methods to improve the genetic diversity. Research the possibility of bringing back extinct species. Examine species restoration methods and techniques. Explore the possibility of de-extinction of a species, its ecological impacts, moral implications and economic values.	Given a factor that may impact the ecosystem (e.g., weather event, pesticide, climate change) predict the influence of the impact on the ecosystem. Predict which species would be most vulnerable to extinction and which species would be most resilient. Defend your reasoning. Examine the established programs to repopulate endangered animal species. Pick a species involved in the restoration and describe current methodology and costs of these programs. Project the benefits to society and why these species are critical to their ecosystem. Examine the role of social media, national economy, politics, energy use, commercial interests, and local traditions in the decision-making process.	Explore a region of the world that is experiencing high rates of extinction and examine the cause. Analyze the impact of extinction on keystone species, food webs, niches and cycling of matter. Discuss the limitations of zoos, arboretums and botanical gardens as defenses against global biodiversity loss.	List historical events that have that resulted in species extinction. Categorize recent causes of extinction of species (e.g., overharvesting, habitat loss). Identify possible impacts species extinction has on biological communities.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		Invasive species	
Research an invasive species in Ohio, analyze its ecological and economic impacts on biological and human communities. Identify factors that contribute to the species' success and propose solutions to reduce the ecological and economic impacts of the species.	Investigate the prevalence of invasive species in the local area and the impact these species have on native species.	Explain the impact of various invasive species control methods on invasive and native species populations (e.g., LEWS). Investigate the increase of human disease due to invasion and range expansion of disease vectors (e.g., mosquitoes, ticks). Examine both human and natural means for vector movement (e.g., severe acute respiratory syndrome [SARS], West Nile, Bird Flu, Tsetse fly, nematodes).	Describe common ways invasive species are introduced to a new habitat. Describe the characteristics of successful invasive species. Create a list of invasive species for your local area and identify the native species with which they compete. Relate this to the ecological controls of native species in the area and how the invasive species escapes those (e.g., invasive starlings are more aggressive at defending nest sites than native bluebirds).

Biology continued

B.C: CELLS
B.C.1: Cell structure and function

- Structure, function and interrelatedness of cell organelles
- Eukaryotic cells and prokaryotic cells

B.C.2: Cellular processes

- Characteristics of life regulated by cellular processes
- Photosynthesis, chemosynthesis, cellular respiration, biosynthesis of macromolecules

CONTENT ELABORATION: CELLS

Building on knowledge from middle school (cell theory, cell division and differentiation), this topic focuses on the cell as a system itself (single-celled organism) and as part of larger systems (multicellular organism), sometimes as part of a multicellular organism, always as part of an ecosystem. The cell is a system that conducts a variety of functions associated with life. Details of cellular processes such as photosynthesis, chemosynthesis, cellular respiration and biosynthesis of macromolecules are addressed at this grade level. The concept of the cell and its parts as a functioning biochemical system is more important than just memorizing the parts of the cell.

B.C.1: Cell structure and function

Every cell produces a membrane through which substances pass differentially, maintaining homeostasis. Molecular properties and concentration of the substances determine which molecules pass freely and which molecules require the input of energy. In all but quite primitive cells, a complex network of proteins provides organization and shape. Within the cell are specialized parts that transport materials, transform energy, build proteins, dispose of waste and provide information feedback and movement. Many chemical reactions that occur in some cells of multicellular organisms do not occur in most of the other cells of the organism. Prokaryotes, simple single-celled organisms, are first found in the fossil record about 3.8 billion years ago. Cells with nuclei, eukaryotes, developed one billion years ago and from these increasingly complex multicellular organisms descended.

B.C.2: Cellular processes

Living cells interact with, and can have an impact on, their environment. Carbon is a necessary element that cells acquire from their environment. Cells use carbon, along with hydrogen, oxygen, nitrogen, phosphorous and sulfur, during essential processes like respiration, photosynthesis, chemosynthesis and biosynthesis of macromolecules (e.g., proteins, lipids, carbohydrates). Chemical reactions that occur within a cell can cause the storage or release of energy by forming or breaking chemical bonds. Specialized proteins called enzymes lower the activation energy required for chemical reactions, increasing the reaction rate. Positive and negative feedback mechanisms regulate internal cell functions as external conditions vary. Most cells function within a narrow range of temperature and pH. Variations in external conditions that exceed the optimal range for a cell can affect the rate at which essential chemical reactions occur in that cell. At very low temperatures, reaction rates are slow. High temperatures can irreversibly change the structure of most protein molecules. Changes in pH beyond the optimal range of the cell can alter the structure of most protein molecules and change how molecules within the cell interact.

The sequence of DNA bases on a chromosome determines the sequence of amino acids in a protein. Enzymatic proteins catalyze most chemical reactions in cells. Protein molecules are long, folded chains made from combinations of 20 common amino-acids. The activity of each protein molecule results from its sequence of amino acids and the shape the chain takes as a result of that sequence.

Note 1: *The idea that protein molecules assembled by cells conduct the work that goes on inside and outside the cells in an organism can be learned without going into the biochemical details. It is sufficient for students to know that the molecules involved are different configurations of a few amino acids and that the different shapes of the molecules influence what they do.*

Note 2: *Emphasis is on inputs and outputs of matter and the transfer and transformation of energy in biological processes. Specific steps, names of enzymes, and intermediates of the pathways for these processes are beyond the scope of the standards.*

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
B.C.1: Cell structure and function			
Building a cell membrane			
	Develop an investigation to observe how materials transport across a selectively permeable membrane and how various cells respond to different environmental conditions to maintain a dynamic equilibrium. Construct a model of the phospholipid bilayer and predict the movement of various materials across the membrane.	Use a model of the phospholipid bilayer and demonstrate transport of various materials across a semipermeable membrane that maintains homeostasis. Provide a survival advantage explanation for why some organelles have double membranes.	Identify different types of transport. Determine how materials move across a selectively permeable membrane.
Cell tour			
		Within a cell, model the synthesis of a hormone such as insulin, including modifications, from start to finish.	Identify the interactivity of organelles resulting in cellular processes such as protein synthesis and metabolism.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Microscopy			
	Collect and analyze microscopic organisms from a local pond or stream. Infer evolutionary relationships between organisms according to ancestral traits and derived characteristics like cell parts and multicellularity.	Create a graphic organizer consisting of various cells and cell structures. Organize them according to size. Investigate how each would appear under different types of microscopes.	
Homeostasis and feedback loop			
Research the cause and effect of various homeostatic diseases (e.g., Type 2 diabetes, high blood pressure, gout) and develop solutions to achieve homeostatic balance for patients that suffer from this disease. Suggest an explanation for the increased incidence of diabetes worldwide.	Plan and conduct an investigation that identifies or manipulates feedback mechanisms to maintain homeostasis. Investigations could include heart rate response to exercise, stomate response to moisture and temperature and root development in response to water levels.	Illustrate a model of negative or positive feedback including a sensor, a control center, effectors and variables being regulated.	Compare negative and positive feedback mechanisms.
B.C.2: Cellular Processes			
Fermentation			
Refine a product such as yogurt so that it better addresses dietary concerns, restraints and restrictions (e.g. diabetics, infants, bodybuilders).	Design a lab studying yeast and adjust variables such as temperature, pH and food sources. Use probes or other methods to measure gas exchange.	Provide data from fermentation activities (e.g., Kombucha, sauerkraut) and evaluate variables and outcomes.	Identify the cellular organelles involved in fermentation. Include inputs and outputs required for the process.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Biosynthesis of macromolecules			
Plan and design an investigation using algae, fungi or other microorganisms to biosynthesize a natural product that has commercial applications.	Research various biomolecules found in food. Investigate a food source and identify its biomolecule components. Evaluate and critique popular food options on the market and determine if the nutritional analysis is factual. Using nutritional data create a new marketing promotion for healthier food choices and present findings.	Research various techniques to extract oil or hormones from algae. Infer the structural changes (e.g., cellular inclusions, smooth endoplasmic reticulum proliferation) to the algal cells that these techniques may cause. Which strains of algae utilize the most cost-efficient metabolic pathways for oil or hormone production?	Construct models of various biomolecules. Identify basic building blocks, functions, and location of biomolecules in food and/or the environment.
Enzymes			
	Plan and design an investigation to determine the factors (e.g., temperature, pH, substrate concentration) that affect the activity of enzymes on their substrates (e.g., peroxidase). Research diseases caused by enzymatic deficiencies and propose possible solutions or evaluate how medical breakthroughs have solved the problem (e.g., lactase persistence, adrenoleukodystrophy, mitochondrial disorders).	Using a simulation or data predict the effects of different variables (e.g., temperature, pH, salinity) on enzyme structure and function. Given a graph, interpret and analyze activation energy with optimal pH and temperature.	Identify the structure and function of enzymes and substrates applying models such as lock and key or induced fit.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Photosynthesis and respiration			
Promote awareness of photosynthetic processes as a component of the Earth's CO_2 recycling system. Design a "green" environment (e.g., school, house, microenvironment) that demonstrates sustainable environmental practices, such as vegetated green roof systems to improve air quality. The design should encompass the efficient use of fuel resources and building materials to lower carbon footprint and reduce greenhouse gas emissions. Generate an argument and present data justifying how the design improves sustainability.	Design experiments to study gas exchange in photosynthetic organisms. Analyze the data generated to justify which environmental conditions are the most efficient for the photosynthetic organisms. Probes could be used to measure gas exchange.	Generate a model to depict the role of photosynthesis and cellular respiration in the cycling of matter and energy through biogeochemical cycles.[1]	Identify key organelles, as well as the inputs and outputs of matter and energy, utilized by photosynthesis and cellular respiration.

[1] National Geographic Website-The Earth Has Lungs This website uses satellite imagery to demonstrate the vast planetary breathing system—a giant green machine that pulls enormous quantities of carbon dioxide out of the air, especially in the warmer months. This site is useful for demonstrating the effect of photosynthesis on the Earth's CO_2 recycling system.

Chemistry

INTRODUCTION AND SYLLABUS

COURSE DESCRIPTION

Chemistry is a high school level course, which satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires three units of science. Each course should include inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.

This course introduces students to key concepts and theories that provide a foundation for further study in other sciences as well as advanced science disciplines. Chemistry comprises a systematic study of the predictive physical interactions of matter and subsequent events that occur in the natural world. The study of matter through the exploration of classification, its structure and its interactions is how this course is organized.

Investigations are used to understand and explain the behavior of matter in a variety of inquiry and design scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications. An understanding of leading theories and how they have informed current knowledge prepares students with higher order cognitive capabilities of evaluation, prediction and application.

COURSE CONTENT

The following information may be taught in any order; there is no ODE-recommended sequence.

C.PM: STRUCTURE AND PROPERTIES OF MATTER

C.PM.1: Atomic structure
- Evolution of atomic models/theory
- Electrons
- Electron configurations

C.PM.2: Periodic Table
- Properties
- Trends

C.PM.3: Chemical bonding
- Ionic
- Polar/covalent

C.PM.4: Representing compounds
- Formula writing
- Nomenclature
- Models and shapes (Lewis structures, ball and stick, molecular geometries)

C.PM.5: Quantifying matter

C.PM.6: Intermolecular forces of attraction
- Types and strengths
- Implications for properties of substances
  - Melting and boiling point
  - Solubility
  - Vapor pressure

C.IM: INTERACTIONS OF MATTER

C.IM.1: Chemical reactions
- Types of reactions
- Kinetics
- Energy
- Equilibrium
- Acids/bases

C.IM.2: Gas laws
- Pressure, volume and temperature
- Ideal gas law

C.IM.3: Stoichiometry
- Molecular calculations
- Solutions
- Limiting reagents

NATURE OF SCIENCE HIGH SCHOOL

Nature of Science
One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.

Categories	High School
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Identify questions and concepts that guide scientific investigations. • Design and conduct scientific investigations using a variety of methods and tools to collect empirical evidence, observing appropriate safety techniques. • Use technology and mathematics to improve investigations and communications. • Formulate and revise explanations and models using logic and scientific evidence (critical thinking). • Recognize and analyze explanations and models. • Communicate and support scientific arguments.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	• Various science disciplines use diverse methods to obtain evidence and do not always use the same set of procedures to obtain and analyze data (i.e., there is no one scientific method). o Make observations and look for patterns. o Determine relevant independent variables affecting observed patterns. o Manipulate an independent variable to affect a dependent variable. o Conduct an experiment with controlled variables based on a question or hypothesis. o Analyze data graphically and mathematically. • Science disciplines share common rules of evidence used to evaluate explanations about natural phenomenon by using empirical standards, logical arguments and peer reviews. o Empirical standards include objectivity, reproducibility, and honest and ethical reporting of findings. o Logical arguments should be evaluated with open-mindedness, objectivity and skepticism. • Science arguments are strengthened by multiple lines of evidence supporting a single explanation. • The various scientific disciplines have practices, methods, and modes of thinking that are used in the process of developing new science knowledge and critiquing existing knowledge.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• Science depends on curiosity, imagination, creativity and persistence. • Individuals from different social, cultural, and ethnic backgrounds work as scientists and engineers. • Science and engineering are influenced by technological advances and society; technological advances and society are influenced by science and engineering. • Science and technology might raise ethical, social and cultural issues for which science, by itself, does not provide answers and solutions.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• Science can advance through critical thinking about existing evidence. • Science includes the process of comparing patterns of evidence with current theory. • Some science knowledge pertains to probabilities or tendencies. • Science should carefully consider and evaluate anomalies (persistent outliers) in data and evidence. • Improvements in technology allow us to gather new scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Chemistry continued

C.PM: STRUCTURE AND PROPERTIES OF MATTER
C.PM.1: Atomic structure

- Evolution of atomic models/theory
- Electrons
- Electron configurations

CONTENT ELABORATION: STRUCTURE AND PROPERTIES OF MATTER

C.PM.1: Atomic structure
Physical Science included properties and locations of protons, neutrons and electrons, atomic number, mass number, cations and anions, isotopes and the strong nuclear force which holds the nucleus together. In this course, the historical development of the atomic model and the positions of electrons are explored in greater detail.

Atomic models are constructed to explain experimental evidence and make predictions. The changes in the atomic model over time exemplify how scientific knowledge changes as new evidence emerges and how technological advancements like electricity extend the boundaries of scientific knowledge. Thompson's study of electrical discharges in cathode-ray tubes led to the discovery of the electron and the development of the plum pudding model of the atom. Rutherford's experiment, in which he bombarded gold foil with α-particles, led to the discovery that most of the atom consists of empty space with a relatively small, positively charged nucleus. Bohr used data from atomic spectra to propose a planetary model of the atom in which electrons orbit the nucleus, like planets around the sun. Later, Schrödinger used the idea that electrons travel in waves to develop a model in which electrons travel randomly in regions of space called orbitals (quantum mechanical model).

Based on the quantum mechanical model, it is not possible to predict exactly where electrons are located but there is a region of space surrounding the nucleus in which there is a high probability of finding an electron (electron cloud or orbital). Data from atomic spectra (emission and absorption) gives evidence that electrons can only exist at certain discrete energy levels and not at energies between these levels.

Atoms are usually in the ground state where the electrons occupy orbitals with the lowest available energy. However, the atom can become excited when the electrons absorb a photon with the precise amount of energy (indicated by the frequency of the photon) to move to an orbital with higher energy. Any photon without this precise amount of energy will be ignored by the electron. The atom exists in the excited state for a very short amount of time. When an electron drops back down to the lower energy level, it emits a photon that has energy equal to the energy difference between the levels. The amount of energy is indicated by the frequency of the light that is given off and can be measured. Each element has a unique emission and absorption spectrum due to its unique electron configuration and specific electron energy jumps that are possible for that element.

Being aware of the quantum mechanical model as the currently accepted model for the atom is important for science literacy as it explains and predicts subatomic interactions, but details should be reserved for more advanced study.

Electron energy levels consist of sublevels (s, p, d and f), each with a characteristic number and shape of orbitals. Orbital diagrams and electron configuration can be constructed to show the location of the electrons in an atom using established rules. Valence electrons are responsible for most of the chemical properties of elements. In this course, electron configuration (extended and noble gas notation) and orbital diagrams can be shown for any element in the first three periods.

Although the quantum mechanical model of the atom explains the most experimental evidence, other models can still be helpful. Thinking of atoms as indivisible spheres is useful in explaining many physical properties of substances, such as the state (solid, liquid or gas) of a substance at room temperature. Bohr's planetary model is useful to explain and predict periodic trends in the properties of elements.

Note: *Quantum numbers and equations of de Broglie, Schrödinger and Plank are beyond the scope of this course.*

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
C.PM.1: Atomic structure			
Evolution of atomic models/atomic structure			
		Compare the nature of protons, neutrons and electrons among different atomic models. Compare the strengths and limitations of particular atomic models. Investigate the principles used to develop atomic models (e.g. a black-box problem). Create a timeline that shows major discoveries in atomic history. Predict which isotope is most abundant given an element's atomic mass and the mass numbers of its isotopes.	Identify atomic models (e.g., Dalton's, Thomson's, Rutherford's, Bohr's) and the work used to produce each of these models. Interpret the classic historical experiments that were used to identify the components of an atom and behavior of electrons. Calculate atomic mass given the abundance of various isotopes. Determine the atomic number, mass number, number of protons, neutrons and electrons.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Electrons			
Using knowledge and/or understanding of various ions and their electron location, construct a plan or proposal for a community firework show. Proposal must contain a list of materials, including the chemicals, safety procedures, environmental impact and possible cost. Design a toy that is based on the idea of excited electrons.	Design an investigation using group 2 elements that illustrates the reactivity of the elements as you move down the group. Interpret data to explain this reasoning based on the electron configurations of each element.	Compare the electron configuration of various ions based on data from an experiment (e.g., flame test, spectral tubes). Explore the color of various salts by looking at the electromagnetic spectrum.	Identify the extended and noble gas notation electron configurations for elements in the first three periods. Using the periodic table, determine the electron configuration of an atom. Construct an orbital diagram or electron configuration to show the probable arrangement of electrons in an atom.

Chemistry continued

C.PM: STRUCTURE AND PROPERTIES OF MATTER
C.PM.2: Periodic table

- Properties
- Trends

CONTENT ELABORATION: STRUCTURE AND PROPERTIES OF MATTER

C.PM.2: Periodic table
In the Physical Science course, the concept that elements are placed in order of increasing atomic number in the periodic table such that elements with similar properties are placed in the same column is introduced. How the periodic table is divided into groups, families, periods, metals, nonmetals and metalloids is also included and will be revisited here. In this course, with more information about the electron configuration of elements, similarities in the configuration of the valence electrons for a particular group can be observed. The electron configuration of an atom can be determined from the position on the periodic table. The repeating pattern in the electron configuration for elements on the periodic table explains many of the trends in the properties observed. Atomic theory is used to describe and explain trends in properties across periods or down columns including atomic radii, ionic radii, first ionization energies, electronegativities and whether the element is a solid or gas at room temperature. Additional ionization energies, electron affinities and periodic properties of the transition elements, and the lanthanide and actinide series are reserved for more advanced study.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
C.PM.2: Periodic table			
Properties			
Develop a proposal for the construction of an outdoor art installation in various environments/climates. Determine which metal(s) would have the optimal properties for your project. Present and defend your proposal to a panel of experts.		Predict the placement of an element on the periodic table given only a list of its properties. Given a metalloid, judge whether the metalloid is more likely to behave as a metal or nonmetal. Defend your choice.	Create a product that explains the organization of the periodic table (e.g., increasing atomic number, groups, periods, metals, metalloid, nonmetals) to middle school students.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Trends			
		Create a graphic to show the relationships between the trends of the periodic table and electron configurations.	Describe ionization energy and relate it to atomic structure. Describe electronegativity and relate it to atomic structure. Describe periodic trends in ionic radii and electron affinity and relate them to atomic structure. Describe atomic radius and relate to atomic structure. Describe how shielding effect explains the trend in atomic size. For two atoms, identify the one that is larger, more electronegative, or more easily ionized based on where they are on the periodic table. Justify your answer.

Chemistry continued

C.PM: STRUCTURE AND PROPERTIES OF MATTER
C.PM.3: Chemical bonding

- Ionic
- Polar/covalent

CONTENT ELABORATION: STRUCTURE AND PROPERTIES OF MATTER

C.PM.3: Chemical bonding
Content in the Physical Science course included recognizing that atoms with unpaired electrons tend to form ionic and covalent bonds with other atoms, forming molecules, ionic lattices or network covalent structures. In this course, electron configuration, electronegativity values and energy considerations will be applied to bonding and the properties of materials with different types of bonding.

Atoms of many elements are more stable when they are bonded to other atoms. In such cases, as atoms bond, energy is released to the surroundings, resulting in a system with lower energy. An atom's electron configuration, particularly the valence electrons, determines how an atom interacts with other atoms. Molecules, ionic lattices and network covalent structures have different, yet predictable, properties that depend on the identity of the elements and the types of bonds formed.

Differences in electronegativity values can be used to predict where a bond fits on the continuum between ionic and covalent bonds. The polarity of a bond depends on the electronegativity difference and the distance between the atoms (bond length). Polar covalent bonds are introduced as an intermediary between ionic and pure covalent bonds. The concept of metallic bonding is also introduced to explain many of the properties of metals (e.g., conductivity). Since most compounds contain multiple bonds, a substance may contain more than one type of bond. Carbon atoms can bond together and with other atoms, especially hydrogen, oxygen, nitrogen and sulfur, to form chains, rings and branching networks that are present in a variety of important compounds, including synthetic polymers, fossil fuels and the large molecules essential to life. Detailed study of the structure of molecules responsible for life is reserved for more advanced courses.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
C.PM.3: Chemical bonding			
Ionic bonds			
Design a theoretical pharmaceutical with an appropriate shape to interact with a provided enzyme or receptor designed by the teacher. The designed molecule would need to contact the enzyme or receptor in three different loci. Design an investigation to evaluate the claims of a commercial product (e.g., ionic-tourmaline, a mineral that is said to emit quick-drying ions; a hair dryer; a shake weight dumbbell; a type of strong-bond glue). Determine function, intent and any potential bias with the product. Present findings in multiple formats.	Design and conduct an investigation to distinguish between ionic, polar covalent, nonpolar covalent and metallic bonds based on material properties (e.g., melting point, solubility, conductivity). Design an experiment to test the effectiveness of a water softener system's ability to remove ions from water.	Compare the stability of ions when they are separated vs. when they are in their lattice. Construct models or diagrams (e.g., Lewis dot structures, ball and stick models) of common compounds and molecules (e.g., NaCl, SiO_2, O_2, H_2, CO_2) and distinguish between ionically and covalently bonded compounds. Using electron configurations, hypothesize how an atom becomes a cation or anion and illustrate how and why they would form ionic compounds.	Define bond energy and recognize that bond-breaking is an endothermic process and bond-forming is an exothermic process. Represent the formation of a bond using electron configurations of individual atoms. Explain the tendency of elements to transfer or share electrons based on their location on the periodic table. Identify valence electrons as the highest energy electrons in the atom and use the octet rule to predict the most stable ion formed.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Polar/covalent bonds			
Propose a method to evaluate the ability of plastics to be recycled based on the understanding of the plastic's polarity. Evaluate and critique the impact of a synthetic polymer, fossil fuel or biological macromolecule on society, the environment or health.	Devise a procedure to evaluate physical and chemical properties to develop predictions and support claims about compounds' classification as ionic, polar or covalent. Evaluate the properties of DNA based on the bonds (polar and nonpolar) within its chemical structure and how it relates to DNA sequencing and/or forensic/medical applications.	Determine if bonds and molecules are polar by determining the direction of dipole moment of the individual bonds. Using electron dot diagrams, generate models showing that molecular compounds result from atoms sharing electrons. Include carbon bonds showing the formation of chains, rings and branching networks. Distinguish between bond polarity and molecular polarity. Construct models illustrating how a nonpolar molecule can be formed from polar bonds. Compare the stability of atoms when they are separated vs. when they are bonded. Using experimental evidence, explain how the properties of macromolecules depend on the properties of the molecules used in their formation and the length and structure of the polymer chain.	Distinguish between ionic and polar/nonpolar covalent bonds based on their electronegativity values. Write equations for covalent bond formation between two atoms using Lewis structures. Explain the difference between a single, double and triple bond in terms of electrons shared. Compare the bond energies and lengths for single, double and triple bonds conceptually (no numbers). Explain how polymerization forms long chains of macromolecules (polymers) from small molecules (monomers). Provide examples of natural and synthetic polymers.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Metallic bonds			
Critique the advantages and disadvantages of different metals and alloys for bridge construction.		Illustrate how freely moving electrons in metallic bonds affect properties such as conductivity, malleability and ductility. Explain how the structure of metal atoms give them the ability to conduct heat and electricity. Explore the extent to which a variety of solid materials conduct electricity and rank the materials from good conductors to poor conductors. Based on the conductivity data, determine patterns of location on the Periodic Table for the good conductors vs. the poor conductors.	Compare electrons in a metallic bond and in a covalent bond.

Chemistry continued

C.PM: STRUCTURE AND PROPERTIES OF MATTER
C.PM.4: Representing compounds

- Formula writing
- Nomenclature
- Models and shapes (Lewis structures, ball and stick, molecular geometries)

CONTENT ELABORATION: STRUCTURE AND PROPERTIES OF MATTER

C.PM.4: Representing compounds
Using the periodic table, formulas of ionic compounds containing specific elements can be predicted. This can include ionic compounds made up of elements from groups 1, 2, 17, hydrogen, oxygen and polyatomic ions (given the formula and charge of the polyatomic ion). Given the formula, a compound can be named using conventional systems that include Greek prefixes and Roman numerals where appropriate. Given the name of an ionic or covalent substance, formulas can be written.

Many different models can be used to represent compounds including chemical formulas, Lewis structures, and ball and stick models. These models can be used to visualize atoms and molecules and to predict the properties of substances. Each type of representation provides unique information about the compound. Different representations are better suited for particular substances. Lewis structures can be drawn to represent covalent compounds using a simple set of rules and can be combined with valence shell electron pair repulsion (VSEPR) theory to predict the three-dimensional electron pair and molecular geometry of compounds. Lewis structures and molecular geometries will only be constructed for the following combination of elements: hydrogen, carbon, nitrogen, oxygen, phosphorus, sulfur and the halogens. Organic nomenclature is reserved for more advanced courses.

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
C.PM.4: Representing compounds			
Formula writing			
		Develop the formulas for chemical compounds in household items based on their names. Construct a prototype of a game to enhance the understanding of formula writing and nomenclature. Allow other students to evaluate and critique the appropriateness of the game.	Given elements from the periodic table and/or polyatomic ions, predict the formula of a compound. Write a formula from the name of an acid.
Nomenclature			
			Given the formula of an ionic compound or a binary covalent compound, determine the compound's name. Name an acid based on its chemical formula.
Models and shapes (Lewis structures, ball and stick, molecular geometries)			
		Determine which type of model (e.g., chemical formula, Lewis structure, ball-and-stick model) is the best representation for a variety of compounds. Implementing VSEPR identify the different shapes within a large macromolecule (e.g., caffeine, dopamine, serotonin).	Construct simple Lewis structures of compounds made up of hydrogen, carbon, nitrogen, oxygen, phosphorus, sulfur and the halogens. Predict the three-dimensional shapes of simple Lewis structures using valence shell electron pair repulsion (VSEPR) theory. Construct three-dimensional ball-and-stick models to determine the shapes of simple covalent compounds.

Chemistry continued

C.PM: STRUCTURE AND PROPERTIES OF MATTER
C.PM.5: Quantifying matter

CONTENT ELABORATION: STRUCTURE AND PROPERTIES OF MATTER

C.PM.5: Quantifying matter
In earlier grades, properties of materials were quantified with measurements that were always associated with some error. In this course, scientific protocols for quantifying the properties of matter accurately and precisely are studied. Using the International System of Units (SI), significant digits or figures, scientific notation, error analysis and dimensional analysis are vital to scientific communication.

There are three domains of magnitude in size and time: the macroscopic (human) domain, the cosmic domain and the submicroscopic (atomic and subatomic) domain. Measurements in the cosmic domain and submicroscopic domains require complex instruments and/or procedures.

Matter can be quantified in a way that macroscopic properties such as mass can reflect the number of particles present. Elemental samples are a mixture of several isotopes with different masses. The atomic mass of an element is calculated given the mass and relative abundance of each isotope of the element as it exists in nature. Because the mass of an atom is very small, the mole is used to translate between the atomic and macroscopic levels. A mole is equal to the number of atoms in exactly 12 grams of the isotope carbon-12. The mass of one mole of a substance is equal to its molar mass in grams. The molar mass for a substance can be used in conjunction with Avogadro's number and the density of a substance to convert between mass, moles, volume and number of particles of a sample.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
C.PM.5: Quantifying matter			
Devise a method to indirectly determine the value of a measurement that common laboratory tools cannot provide (e.g., thickness of aluminum foil, number of sand particles, moles of chalk used to write your name, drop from a pipet).	Design a method to determine the empirical formula or percent composition of an unknown hydrate/compound. Determine the percent by mass of water content in popcorn. Correlate its effect on the amount of popcorn produced (or time it takes to start the batch popping). Compare three brands, isolate other variables (e.g., popping method, use of different types of oil) and present findings in multiple formats.	Using a Socratic seminar, research and discuss the pros and cons of the International System of Units (SI) vs. the English measuring system. Use calculations to compare the ratios of the size of the atom to the size of different objects (e.g., cell, person, tree). Compare moles and mass. Identify situations where each is most appropriate to use. Design an investigation to show that the volume of any liquid sample is constant when divided by its mass.	Measure the volume of an irregular solid using SI units. Provide your answer using correct significant figures and unit. Distinguish accuracy from precision. Carry out laboratory measurements with a variety of equipment (e.g., graduated cylinders, beakers, balances) and report measurements to the correct number of significant figures. Compare the accuracy of each measuring device. Apply the rules for determining significant digits when performing mathematical operations. Determine the average atomic mass of an element based on the percent abundance of its naturally occurring isotopes. Convert between mass, moles, volume and number of representative particles using Avogadro's number, molar mass and density using dimensional analysis.

Chemistry continued

C.PM: STRUCTURE AND PROPERTIES OF MATTER
C.PM.6: Intermolecular forces of attraction

- Types and strengths
- Implications for properties of substances
    - Melting and boiling point
    - Solubility
    - Vapor pressure

CONTENT ELABORATION: STRUCTURE AND PROPERTIES OF MATTER

C.PM.6: Intermolecular forces of attraction
In middle school, solids, liquids and gases were explored in relation to the spacing of the particles, motion of the particles and strength of attraction between the particles that make up the substance. The intermolecular forces of attraction between particles that determine whether a substance is a solid, liquid or gas at room temperature are addressed in greater detail in this course. Intermolecular attractions are generally weak when compared to intramolecular bonds, but span a wide range of strengths.

The composition of a substance and the shape and polarity of a molecule are particularly important in determining the type and strength of bonding and intermolecular interactions. Types of intermolecular attractions include London dispersion forces (present between all molecules), dipole-dipole forces (present between polar molecules) and hydrogen bonding (a special case of dipole-dipole where hydrogen is bonded to a highly electronegative atom such as fluorine, oxygen or nitrogen), each with its own characteristic relative strength.

The configuration of atoms in a molecule determines the strength of the forces (bonds or intermolecular forces) between the particles and therefore the physical properties (e.g., melting point, boiling point, solubility, vapor pressure) of a material. For a given substance, the average kinetic energy (temperature) needed for a change of state to occur depends upon the strength of the intermolecular forces between the particles. Therefore, the melting point and boiling point depend upon the amount of energy that is needed to overcome the attractions between the particles. Substances that have strong intermolecular forces or are made up of three-dimensional networks of ionic or covalent bonds, tend to be solids at room temperature and have high melting and boiling points. Nonpolar organic molecules are held together by weak London dispersion forces. However, substances with longer chains provide more opportunities for these attractions and tend to have higher melting and boiling points. Increased branching of organic molecules results in lower melting and boiling points due to interference with the intermolecular attractions.

Substances will have a greater solubility when dissolving in a solvent with similar intermolecular forces. If the substances have different intermolecular forces, they are more likely to interact with themselves than the other substance and remain separated from each other. Water is a polar molecule and it is often used as a solvent since most ionic and polar covalent substances will dissolve in it. In order for an ionic substance to dissolve in water, the attractive forces between the ions must be overcome by the dipole-dipole interactions with the water. Dissolving of a solute in water is an example of a process that is difficult to classify as a chemical or physical change and it is not appropriate to have students classify it one way or another.

Evaporation occurs when the particles with enough kinetic energy to overcome the attractive forces separate from the rest of the sample to become a gas. The pressure of these particles is called vapor pressure. Vapor pressure increases with temperature. Particles with larger intermolecular forces have lower vapor pressures at a given temperature since the particles require more energy to overcome the attractive forces between them. Molecular substances often evaporate more due to the weak attractions between the particles and can often be detected by their odor. Ionic or network covalent substances have stronger forces and are not as likely to volatilize. These substances often have little, if any, odor. Liquids boil when their vapor pressure is equal to atmospheric pressure. In solid water, there is a network of hydrogen bonds between the particles that gives it an open structure. This is why water expands as it freezes and why solid water has a lower density than liquid water. This has important implications for life (e.g., ice floating on water acts as an insulator in bodies of water to keep the temperature of the rest of the water above freezing).

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C.PM.6: Intermolecular forces of attraction			
Types and strengths			
	Design an investigation to identify which solvent would be best to dissolve a particular solute. Design a procedure to determine the polarity of a substance. Investigate why water doesn't follow predicted trends (e.g., surface tension, density, vapor pressure, boiling point) based on its intermolecular interactions (e.g. drops on a penny, capillary tube, mixing oil and water, water on glass vs. wax paper). Summarize your findings.	Apply the idea of intermolecular forces to biological implications (e.g., hydrogen bonding between two DNA strands, cell membrane formation of lipids). Construct a chromatography technique to separate the components of different dyes (e.g., hair color, food additives, skittles) applying principles of inter- and intra-molecular forces. Illustrate the differences between intermolecular forces. Represent the cause of intermolecular forces between molecules using models. Explain the effect that branching has on London dispersion forces in nonpolar organic molecules (e.g., long chains have greater forces and branching decreases the forces). Identify real-world implications.	Explain the importance of molecular-level structure in the functioning of designed materials (e.g., why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, pharmaceuticals are designed to interact with specific receptors). Describe intermolecular forces for molecular compounds. • H-bond as attraction between molecules when H is bonded to O, N, or F. • Dipole-dipole attractions between polar molecules. • London dispersion forces (electrons of one molecule attracted to nucleus of another molecule) – i.e. liquefied inert gases. • Relative strengths (H>dipole>London/van der Waals).

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
			Explain why intermolecular forces are weaker than ionic, covalent or metallic bonds. Identify the intermolecular forces that exist in a given compound.
Implications for properties of substances (melting and boiling point, solubility, vapor pressure)			
Make a soap and evaluate its effectiveness on hard water. Compare the effectiveness of various soaps. Evaluate the composition of shampoo samples using properties (e.g., viscosity, pH) to determine their effectiveness.	Evaluate the properties of sweeteners (e.g., regular table sugar, high fructose corn syrup, stevia, aspartame, saccharin, sucralose, honey, agave). Research these products and potential impacts. A variation for this could be evaluating oils (e.g., canola, coconut, olive, vegetable). Design an investigation to determine if a molecule is polar or nonpolar. Devise an investigation to show that the addition of a solute affects the density of a liquid.	Explain how a graph of vapor pressure vs. temperature can be used to determine boiling point and strength of intermolecular forces. Demonstrate the effect the strength of intermolecular forces has on various properties (e.g., change in evaporation temperature, polarizability, viscosity). Predict which compound will have the highest/lowest vapor pressure and melting/boiling point based on intermolecular forces. Sketch the solvation of a solute in an appropriate solvent and explain how the solute separates and interacts with the solvent.	Differentiate between bond polarity and molecular polarity. Explain why greater solubility occurs when dissolving a substance in a solvent with similar intermolecular forces ("like dissolves like").

Chemistry continued

C.IM: INTERACTIONS OF MATTER
C.IM.1: Chemical reactions

- Types of reactions
- Kinetics
- Energy
- Equilibrium
- Acids/bases

CONTENT ELABORATION: INTERACTIONS OF MATTER

C.IM.1: Chemical reactions
In the Physical Science course, coefficients were used to balance simple equations. Other representations, including Lewis structures and three-dimensional models, were also used and manipulated to demonstrate the conservation of matter in chemical reactions. In this course, more complex reactions will be studied, classified and represented with balanced chemical equations and three-dimensional models.

Classifying reactions into types can be a helpful organizational tool for recognizing patterns of what may happen when two substances are mixed. Teachers should be aware that the common reaction classifications that are often used in high school chemistry courses may lead to misconceptions because they are not based on the actual chemistry, but on surface features that can be similar from one system to another (e.g., exchanging partners), even though the underlying chemistry is not the same. However, these classifications may be useful in making predictions about what happens when two substances are mixed.

Some general types of chemical reactions are oxidation/reduction, synthesis, decomposition, single replacement, double replacement (including precipitation reactions and some acid-base neutralizations) and combustion reactions. Some reactions can fit into more than one category. For example, a single replacement reaction can also be classified as an oxidation/reduction reaction. Identification of reactions involving oxidation and reduction as well as indicating what substance is being oxidized and what is being reduced are appropriate in this course. However, balancing complex oxidation/reduction reactions is reserved for more advanced study.

Organic molecules release energy when undergoing combustion reactions and are used to meet the energy needs of society (e.g., oil, gasoline, natural gas) and to provide the energy needs of biological organisms (e.g., cellular respiration). When a reaction between two ionic compounds in aqueous solution results in the formation of a precipitate or molecular compound, the reaction often occurs because the new ionic or covalent bonds are stronger than the original ion-dipole interactions of the ions in solution. Laboratory experiences (3-D or virtual) with different types of chemical reactions should be provided.

Reactions occur when reacting particles collide in an appropriate orientation and with sufficient energy. The rate of a chemical reaction is the change in the amount of the reactants or products in a specific period of time. Increasing the probability or effectiveness of the collisions between the particles increases the rate of the reaction. Therefore, changing the concentration of the reactants, changing the temperature or the pressure of gaseous reactants, or using a catalyst, can change the reaction rate. Likewise, the collision theory can be applied to dissolving solids in a liquid solvent and can be used to explain why reactions are more likely to occur between reactants in the aqueous or gaseous state than between solids. The rate at which a substance dissolves should not be confused with the amount of solute that can dissolve in a given amount of solvent (solubility). Mathematical treatment of reaction rates is reserved for more advanced study. Computer simulations can help visualize reactions from the perspective of the kinetic-molecular theory.

In middle school, the differences between potential and kinetic energy and the particle nature of thermal energy were introduced. For chemical systems, potential energy is in the form of chemical energy and kinetic energy is in the form of thermal energy. The total amount of chemical energy and/or thermal energy in a system is impossible to measure. However, the energy change of a system can be calculated from measurements (mass and change in temperature) from calorimetry experiments in the laboratory. Conservation of energy is an important component of calorimetry equations. Thermal energy is the energy of a system due to the movement of its particles. The thermal energy of an object depends upon the amount of matter present (mass), temperature and chemical composition.

Some materials require little energy to change their temperature and other materials require a great deal to change their temperature by the same amount. Specific heat is a measure of how much energy is needed to change the temperature of a specific mass of material a specific amount. Specific heat values can be used to calculate the thermal energy change, the temperature (initial, final or change in) or mass of a material in calorimetry. Water has a particularly high specific heat capacity, which is important in regulating Earth's temperature.

As studied in middle school, chemical energy is the potential energy associated with chemical systems. Chemical reactions involve valence electrons forming bonds to yield more stable products with lower energies. Energy is required to break interactions and bonds between the reactant atoms and energy is released when an interaction or bond is formed between the atoms in the products. Molecules with weak bonds (e.g., ATP) are less stable and tend to react to produce more stable products, releasing energy in the process. Generally, energy is transferred out of the system (exothermic) when the products have stronger bonds than the reactants and is transferred into the system (endothermic) when the reactants have stronger bonds than the products. Predictions of the energy requirements (endothermic or exothermic) of a reaction can be made given a table of bond energies. Graphic representations can be drawn and interpreted to represent the energy changes during a reaction. The role of energy in determining the spontaneity of chemical reactions is dealt with conceptually in this course. Entropy and its influence on the spontaneity of reactions are reserved for more advanced study.

All reactions are reversible to a degree and many reactions do not proceed completely toward products but appear to stop progressing before the reactants are all used up. At this point, the amounts of the reactants and the products appear to be constant and the reaction can be said to have reached dynamic equilibrium. Dynamic equilibrium means the rate of the reverse reaction is equal to the rate of the forward reaction so there is no apparent change in the reaction.

If a chemical system at equilibrium is disturbed by a change in the conditions of the system (e.g., increase or decrease in the temperature, pressure on gaseous equilibrium systems, concentration of a reactant or product), then the equilibrium system will respond by shifting to a new equilibrium state, reducing the effect of the change (Le Chatelier's Principle). If products are removed as they are formed during a reaction, then the equilibrium position of the system is forced to shift to favor the products. In this way, an otherwise unfavorable reaction can be made to occur. Mathematical treatment of equilibrium reactions is reserved for advanced study. Computer simulations can help visualize the progression of a reaction to dynamic equilibrium and the continuation of both the forward and reverse reactions after equilibrium has been attained.

Properties of acids and bases and the ranges of the pH scale were introduced in Physical Science. In this course, the structural features of molecules are explored to further understand acids and bases. Acids often result when hydrogen is covalently bonded to an electronegative element and is easily dissociated from the rest of the molecule to bind with water to form a hydronium ion (H3O+). The acidity of an aqueous solution can be expressed as pH, where pH can be calculated from the concentration of the hydronium ion. Bases are likely to dissociate in water to form a hydroxide ion. Acids can react with bases to form a salt and water. Such neutralization reactions can be studied quantitatively by performing titration experiments. Detailed instruction about the equilibrium of acids and bases and the concept of Brønsted-Lowry and Lewis acids and bases is not the focus at this level.

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C.IM.1: Chemical reactions			
Types of reactions			
Evaluate oxidation-reduction reactions occurring in real-world settings (e.g., rusting, electroplating) that cause engineering/manufacturing challenges and propose a solution.	Generate a process for recycling a metal including the uses and possible limitations of the recycled metal.	Apply knowledge of reactions to determine the appropriate fire extinguisher for a given scenario. Examine living organisms to identify and explain biological chemical reactions (e.g., metabolism, respiration, photosynthesis) within the organism. Compare different reaction types. Explain the energy changes in photosynthesis and in the combustion of sugar in terms of bond breaking and bond formation. Using activity series and solubility rules construct an outcome for single replacement and double replacement reactions. Draw a particle diagram representing the interactions of particles in a chemical reaction.	Classify a chemical reaction as synthesis, decomposition, single-replacement, double replacement or organic combustion. Identify which substance is oxidized and which substance is reduced in an oxidation/reduction reaction.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Kinetics			
Critique the effects of a catalyst on everyday chemical reactions (e.g., biological enzymes, catalytic converters). Redesign a process which is more cost effective and/or environmentally friendly.	Design an experiment to determine the effect of concentration, surface area or temperature on reaction rate.	Apply scientific principles and evidence to provide an explanation about the effects of changing concentration, temperature and pressure on the rate of a chemical reaction. Through experimentation, generate qualitative potential energy diagrams for endothermic and exothermic reactions with and without the presence of a catalyst (e.g., decomposition of H_2O_2 with KI and without KI). Include reactants, products and activated complex. Illustrate collision theory using particle diagrams showing that molecules must collide in the proper orientation and with sufficient energy to equal or exceed the activation energy in order to react.	Identify the ways the rate of a chemical reaction can be affected (e.g., concentrations of reactions, surface area, changing temperature or pressure of gaseous substances, using a catalyst).
Energy			
Design a better (e.g., less expensive, more environmentally friendly) safe hand warmer using ionic substances.	Design a method to determine the identity of a metal by calculating the heat transfer from the hot metal to cold water.	Compare how the specific heat of different substances impacts temperature change. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. Use household materials to show the difference between endothermic and exothermic reactions.	Calculate the thermal energy change (q), the change of temperature (ΔT), initial or final temperature and mass of a material using specific heat. Given a table of bond energies, determine whether a given reaction is exothermic or endothermic. Track the flow of energy and explain why a reaction is an exothermic or endothermic process.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		Equilibrium	
Propose a procedure to shift a commercial equilibrium process to maximize a desired product and construct a risk assessment for its implications on society (e.g., Haber process).		In a laboratory setting, illustrate equilibrium shift due to disturbances. Indicate whether the forward or reverse reaction is favored to reach equilibrium based on different disturbances (e.g., increase or decrease in temperature, pressure on gaseous equilibrium systems, change in concentration of a reactant or product).	Show that equilibrium is dynamic and that the rates of the forward and reverse reactions are equal. Describe key features of equilibrium (two opposing processes occur simultaneously at the same rate).
		Acids/bases	
Conduct an experiment to determine what type of roof materials would be appropriate in areas with high acid rain. Evaluate and critique why lakes with limestone or calcium carbonate experience less adverse effects from acid rain than lakes with granite beds. Then invent a product or process to minimize these effects.	Design an investigation to determine the effective pH range of natural and synthetic indicators. Devise a method to evaluate the Vitamin C content of commercial products. Design an investigation to determine the most effective antacid (e.g., baking soda ($NaHCO_3$) or magnesium hydroxide ($Mg(OH)_2$) per gram for neutralizing stomach acid (HCl).	Evaluate neutralization reactions quantitatively by performing titration experiments.	Perform calculations relating pH to hydronium ion concentration. Identify acids based on the formation of the hydronium ion in water. Identify bases by their dissociation in water to form the hydroxide ion.

Chemistry continued

C.IM: INTERACTIONS OF MATTER
C.IM.2: Gas laws

- Pressure, volume and temperature
- Ideal gas law

CONTENT ELABORATION: INTERACTIONS OF MATTER

C.IM.2: Gas laws
The kinetic-molecular theory can be used to explain the properties of gases (pressure, temperature and volume) through the motion and interactions of its particles. Problems can also be solved involving the changes in temperature, pressure, volume and amount of a gas. When two of these four are kept constant, the relationship between the other two can be quantified, described and explained using the kinetic-molecular theory. Real-world phenomena (e.g., why tire pressure increases in hot weather, why a hot air balloon rises) can be explained using this theory. When solving gas problems, the Kelvin temperature scale must be used since only in this scale is the temperature directly proportional to the average kinetic energy. The Kelvin temperature is based on a scale that has its minimum temperature at absolute zero, a temperature at which all motion theoretically stops. Since equal volumes of gases at the same temperature and pressure contain an equal number of particles (Avogadro's law), problems can be solved for an unchanging gaseous system using the ideal gas law ($PV = nRT$) where R is the ideal gas constant (e.g., represented in multiple formats, 8.31 joules/(mole·K). The focus in this course is solving problems using the gas laws and understanding their applications, rather than memorizing the specific names and formulas. Deviations from ideal gaseous behavior are reserved for more advanced study. Relationships between the volume, temperature and pressure can be explored in the laboratory or through computer simulations or virtual experiments.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
C.IM.2: Gas laws			
Pressure, volume and temperature			
Design a device that measures tire pressure under changing temperature conditions. Design a toy that is an application of a gas law.	Using simulations and/or laboratory experiences, determine the relationships between pressure and volume, pressure and temperature, and temperature and volume.	Explain both the quantitative and qualitative relationships between pressure, volume and temperature. Construct models representing the relationship of pressure, volume and temperature related to collisions and energy of particles. Apply gas laws to common scenarios (e.g. hot air balloons, tire blowouts) Use the kinetic molecular theory to explain the motion of gas particles and how they are affected by changes in pressure, temperature and/or volume.	Identify units of pressure, volume and temperature. Convert between different pressure units. Solve problems using appropriate gas law equations. Determine whether pressure, temperature and volume are increasing or decreasing in a given situation.
Ideal gas law			
	Create a model airbag with baking soda and vinegar in a plastic bag. Use the ideal gas law to figure the amount of the reactants necessary to fill a given plastic bag. Test the prediction and provide possible explanations for any discrepancy between the theoretical and actual results. Detect and measure the volume of a gas produced during a chemical reaction and relate to molar volume at standard temperature and pressure.	Use an Ideal Gas Law Simulator to represent and interpret the connection between pressure, volume, temperature and number of particles.	Apply the ideal gas law to solve for an appropriate variable.

Chemistry continued

C.IM: INTERACTIONS OF MATTER
C.IM.3: Stoichiometry

- Molar calculations
- Solutions
- Limiting reagents

CONTENT ELABORATION: INTERACTIONS OF MATTER

C.IM.3: Stoichiometry
A stoichiometric calculation involves the conversion from the amount of one substance in a chemical reaction to the amount of another substance. The coefficients of the balanced equation indicate the ratios of the substances involved in the reaction in terms of both particles and moles.

Once the number of moles of a substance is known, amounts can be changed to mass, volume of a gas, volume of solutions and/or number of particles. Molarity is a measure of the concentration of a solution that can be used in stoichiometric calculations. When performing a reaction in the lab, the experimental yield can be compared to the theoretical yield to calculate percent yield. The concept of limiting reagents is treated conceptually. Mathematical applications can be utilized, but it is important to address the symbolic representations as well. Molality and normality are concepts reserved for more advanced study.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
C.IM.3: Stoichiometry			
Molar Calculations			
Evaluate the efficiency, cost and environmental impacts of multiple possible chemical processes to determine which process would be best to use. Sustainability and green chemistry should be considered.	Calculate the reactants needed to produce an exact amount of a product (e.g., produce silver through the reaction of silver nitrate and copper or zinc and hydrochloric acid). Produce the product in the laboratory. Calculate the percent difference between the theoretical amount and the amount actually produced. Provide possible explanations for the discrepancy.		Using data collected from a multi-step chemical reaction, calculate percent yield. Use mole ratios from a balanced equation to calculate the quantity of one substance in a reaction, given the quantity of another substance in the reaction (e.g., given moles, particles, mass or volume and ending with moles, particles, mass or volume of the desired substance). Interpret the coefficients of a balanced equation in terms of moles and particles.
Solutions			
	Plan and implement a process to test concentration of pollutants in water (e.g., lead, mercury).	Explain how the creation of a standardized solution (a solution of known molarity) allows you to determine the concentration of an unknown solution.	Create a solution and a dilution of a known concentration. Calculate the molarity of an aqueous solution. Distinguish between solute, solvent and solution. Determine the concentration of an unknown solution through titration.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Limiting reagents			
Evaluate an environmental problem through the lens of limiting reagents (e.g., algae growths impacted by available phosphates and nitrates). Investigate the role that limiting reagents play in an industrial process (e.g., pharmacology, cosmetics, chemical industries). Evaluate techniques to optimize production, including how costs and waste products are taken into consideration.	Plan and carry out an investigation to demonstrate the conceptual principle of limiting reactants.	Compare limiting to excess reagents in a chemical reaction (e.g., copper (II) sulfate and an iron nail).	Determine which reactant is limited using particle diagrams. Use BCA tables to calculate the quantities of products and excess reactants.

Environmental Science

INTRODUCTION AND SYLLABUS

COURSE DESCRIPTION

Environmental science is a high school level course, which satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires three units of science. Each course should include inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.

Environmental science incorporates biology, chemistry, physics and physical geology and introduces students to key concepts, principles and theories within environmental science.

Investigations are used to understand and explain the behavior of nature in a variety of inquiry and design scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications. It should be noted that there are classroom examples in the model curriculum that can be developed to meet multiple sections of the syllabus, so one well-planned long-term project can be used to teach multiple topics.

COURSE CONTENT

The following information may be taught in any order; there is no ODE-recommended sequence.

EARTH SYSTEMS: INTERCONNECTED SPHERES OF EARTH

ENV.ES.1: Biosphere
- Evolution and adaptation in populations
- Biodiversity
- Ecosystems (equilibrium, species interactions, stability)
- Population dynamics

ENV.ES.2: Atmosphere
- Atmospheric properties and currents

ENV.ES.3: Lithosphere
- Geologic events and processes

ENV.ES.4: Hydrosphere
- Oceanic currents and patterns (as they relate to climate)
- Surface and ground water flow patterns and movement
- Cryosphere

ENV.ES.5: Movement of matter and energy through the hydrosphere, lithosphere, atmosphere and biosphere
- Energy transformation on global, regional and local scales
- Biogeochemical cycles
- Ecosystems
- Weather
- Climate

EARTH'S RESOURCES

ENV.ER.1: Energy resources
- Renewable and nonrenewable energy sources and efficiency
- Alternate energy sources and efficiency
- Resource availability
- Mining and resource extraction

ENV.ER.2: Air and air pollution
- Primary and secondary contaminants
- Greenhouse gases
- Clean Air Act

ENV.ER.3: Water and water pollution
- Potable water and water quality
- Hypoxia, eutrophication
- Clean Water Act
- Point source and non-point source contamination

ENV.ER.4: Soil and land
- Desertification
- Mass movement and erosion
- Sediment contamination
- Land use and land management (including food production, agriculture and zoning)
- Solid and hazardous waste

ENV.ER.5: Wildlife and wilderness
- Wildlife and wilderness management
    - Endangered species
- Invasive Species
- Introduced Species

ENV.GP: GLOBAL ENVIRONMENTAL PROBLEMS AND ISSUES

ENV.GP.1: Human Population
ENV.GP.2: Potable water quality, use and availability
ENV.GP.3: Climate change
ENV.GP.4: Sustainability
ENV.GP.5: Species depletion and extinction
ENV.GP.6: Air quality
ENV.GP.7: Food production and availability
ENV.GP.8: Deforestation and loss of biodiversity
ENV.GP.9: Waste management (solid and hazardous)

NATURE OF SCIENCE HIGH SCHOOL

Nature of Science One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.	
Categories	**High School**
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Identify questions and concepts that guide scientific investigations. • Design and conduct scientific investigations using a variety of methods and tools to collect empirical evidence, observing appropriate safety techniques. • Use technology and mathematics to improve investigations and communications. • Formulate and revise explanations and models using logic and scientific evidence (critical thinking). • Recognize and analyze explanations and models. • Communicate and support scientific arguments.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	• Various science disciplines use diverse methods to obtain evidence and do not always use the same set of procedures to obtain and analyze data (i.e., there is no one scientific method). o Make observations and look for patterns. o Determine relevant independent variables affecting observed patterns. o Manipulate an independent variable to affect a dependent variable. o Conduct an experiment with controlled variables based on a question or hypothesis. o Analyze data graphically and mathematically. • Science disciplines share common rules of evidence used to evaluate explanations about natural phenomenon by using empirical standards, logical arguments and peer reviews. o Empirical standards include objectivity, reproducibility, and honest and ethical reporting of findings. o Logical arguments should be evaluated with open-mindedness, objectivity and skepticism. • Science arguments are strengthened by multiple lines of evidence supporting a single explanation. • The various scientific disciplines have practices, methods, and modes of thinking that are used in the process of developing new science knowledge and critiquing existing knowledge.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• Science depends on curiosity, imagination, creativity and persistence. • Individuals from different social, cultural, and ethnic backgrounds work as scientists and engineers. • Science and engineering are influenced by technological advances and society; technological advances and society are influenced by science and engineering. • Science and technology might raise ethical, social and cultural issues for which science, by itself, does not provide answers and solutions.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• Science can advance through critical thinking about existing evidence. • Science includes the process of comparing patterns of evidence with current theory. • Some science knowledge pertains to probabilities or tendencies. • Science should carefully consider and evaluate anomalies (persistent outliers) in data and evidence. • Improvements in technology allow us to gather new scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Environmental Science continued

ENV.ES: EARTH SYSTEMS: INTERCONNECTED SPHERES OF EARTH
ENV.ES.1: Biosphere

- Evolution and adaptation in populations
- Biodiversity
- Ecosystems (equilibrium, species interactions, stability)
- Population dynamics

ENV.ES.2: Atmosphere

- Atmospheric properties and currents

ENV.ES.3: Lithosphere

- Geologic events and processes

ENV.ES.4: Hydrosphere

- Oceanic currents and patterns (as they relate to climate)
- Surface and ground water flow patterns and movement
- Cryosphere

ENV.ES.5: Movement of matter and energy through the hydrosphere, lithosphere, atmosphere and biosphere

- Energy transformations on global, regional and local scales
- Biogeochemical cycles
- Ecosystems
- Weather
- Climate

CONTENT ELABORATION: EARTH SYSTEMS: INTERCONNECTED SPHERES OF EARTH

This topic builds upon both the physical science and biology courses as they relate to energy transfer and transformation, conservation of energy and matter, evolution, adaptation, biodiversity, population studies and ecosystem composition and dynamics. In grades 6-8, geologic processes, biogeochemical cycles, climate, the composition and properties of the atmosphere, lithosphere and hydrosphere (including the hydrologic cycle) are studied. In this course, the focus is on the connections and interactions between Earth's spheres (the hydrosphere, atmosphere, biosphere and lithosphere). Both natural and anthropogenic interactions are studied. This includes an understanding of causes and effects of climate, global climate (including El Niño/La Niña patterns and trends) and changes in climate through Earth's history, geologic events (e.g., volcanic activity or mass wasting) that impact Earth's spheres, biogeochemical cycles and patterns, the effect of abiotic and biotic factors within an ecosystem, and the understanding that each of Earth's spheres is part of the dynamic Earth system. Ground water and surface water velocities and patterns are included as the movement of water (either at the surface, in the atmosphere or beneath the surface) can be a mode of transmission of contamination. This builds upon previous hydrologic cycle studies in earlier grades. Geomorphology and topography are helpful in determining flow patterns and pathways for contamination.

The connections and interactions of energy and matter between Earth's spheres are researched and investigated using actual data. The emphasis is on the interconnectedness of Earth's spheres and the understanding of the complex relationships between them, including both abiotic and biotic factors. One event, such as a petroleum release or a flood, can impact each sphere. Some impacts are long-term, others are short-term and most are a combination of both long- and short-term. It is important to use real, quantifiable data to study the interactions, patterns and cycles among Earth's spheres.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
ENV.ES.1: Biosphere			
Identify an instance of biomagnification or bioaccumulation within a specific ecosystem and propose possible solutions. Evaluate and critique current trends in reclaiming former industrial sites. Taking economics, government regulations and current technology into consideration, design a new method to reclaim a former brownfield in the Great Lakes Region. Research an endangered species and develop a conservation plan for the species taking into account the interests of all stakeholders. List the advantages and disadvantages of conservation.	Plan and implement a population study of a specific area over a period of time or critique/analyze an existing population study. Document changes in weather, food availability and any change to the population. Prepare a scientific analysis and conclusion for the study. Choose two accessible habitats and take a field trip. Choose a level and type of taxa (e.g., birds, insects, spiders, trees, herbaceous plants). Collect data on species diversity and abundance. Compare and contrast data using Simpson's Diversity Index or Shannon-Weiner Index to measure species diversity/abundance and compare the relative health of the two habitats.	Conduct a pond study, calculate biodiversity index and construct a sustainable food web. Research how biomagnification or bioaccumulation impacts specific Ohio ecosystems. Research should include the possible impact to humans. Present research and findings on biomagnification and bioaccumulation impacts on specific Ohio ecosystems (e.g., using "Ohio's Sportfish Consumption Advisory" published annually by the Ohio EPA). Graph survivorship curves to make judgements about environmental and health conditions in various habitats/ecosystems. Evaluate current protection and management laws pertaining to endangered species and their habitats.	Determine the carrying capacity of an ecosystem using historical or current data (e.g., Moose on Isle Royale, Kaibab Deer in Arizona).

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
ENV.ES.2: Atmosphere			
		Explain the effects and causes of El Niño/La Niña weather patterns on Earth's spheres, biogeochemical cycles and biodiversity. Include regional comparisons of the effects of these events.	Complete a foldable or other manipulative on the layers of the Earth's atmosphere, complete with description and chemical composition.
ENV.ES.3: Lithosphere			
		Research and analyze an event (e.g., naturally caused [an Icelandic volcano] or anthropogenically caused [oil spills]) and make a model to demonstrate how the different spheres (e.g., atmosphere, biosphere, lithosphere, hydrosphere) are impacted. Examine human impacts on the lithosphere (e.g., hydraulic fracturing, surface mining, urbanization) and hypothesize possible consequences. Find a large tract of property for sale in your community. Using knowledge of the lithosphere through data found on United States Department of Agriculture's site, make recommendations on how this property could be used in the future. Compare soils found in various parts of the community. Use information gathered to create a soil texture map of the community.	Build a model of the layers of the Earth in order to identify and describe the components and their role in geologic events.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
ENV.ES.4: Hydrosphere			
Construct a functioning shower using only four gallons of water and household materials, which would allow someone to wash the body and hair effectively and capture the gray water produced. The shower construction should be tested to assure it meets design criteria and that it will adequately allow for a person to wash. Investigate various methods to clean up an oil spill using a model to evaluate their effectiveness. At the completion of the clean-up process, each team will assess the effectiveness, including environmental impact of the cleanup process, and make suggestions for improvement. Design methods to transport potable water to arid areas. Consider availability of materials, cost and efficiency.		Create a map of the local watershed including boundaries of adjoining watersheds. Have the map depict movement and direction of water within the watershed. Plan a demonstration to illustrate the factors that lead to changing oceanic currents (both deep and shallow). Research a water resource disaster and describe various ways the disaster has altered the ecosystem of the region. Explain the stability of that ecosystem, as well as how it has changed over time. Use Ohio EPA well water data to compare water composition of a contaminated site with groundwater from your own community.	Use a regional map to identify local water sources and their proximity to schools, neighborhoods and shopping centers. Indicate how those developments may infringe upon the health of the water sources.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
ENV.ES.5: Movement of matter and energy through the hydrosphere, lithosphere, atmosphere and biosphere			
Use quantifiable data and evidence to investigate the relationship between deforestation and changing weather or, in some cases, climate, at a specific location (e.g., the Amazon region of South America). Analyze the data and draw a conclusion based upon the analysis. Research, design, create and maintain a tabletop sustainable biosphere (e.g., eco column) using aquarium gravel, live aquatic plants and aquatic organisms (e.g., fish, ghost shrimp, Sea Monkeys ®). Use it to study nutrient cycling, limiting factors, decomposition, water quality and eutrophication.	Model and describe how toxins enter and accumulate in a food chain. Find and paraphrase laws/regulations which attempt to regulate use of potential contaminants (e.g., DDT, BPA, pharmaceuticals, lead). Research an actual environmental or geologic event (e.g., release of a toxin/contaminant, hurricane, earthquake, volcano, flood, fire, landslide) and determine how each of Earth's spheres was impacted. Include long-term and short-term impacts. Trace the movement of contamination or energy through each sphere. Provide scientific evidence and data to support conclusions. Describe the relationship between ocean surface temperature and hurricane intensity, using the NOAA database. Create a map of the most vulnerable areas and use it to identify highly populated areas that could be affected. Explore, analyze and interpret past and current climate patterns for 10 different cities around the world. Analyze differences between climate patterns. Make predictions of future patterns.	Write an article explaining the difference between climate and weather and the importance of distinguishing between the two.	

Environmental Science continued

ENV.ER: EARTH'S RESOURCES

ENV.ER.1: Energy resources

- Renewable and nonrenewable energy sources and efficiency
- Alternate energy sources and efficiency
- Resource availability
- Mining and resource extraction

ENV.ER.2: Air and air pollution

- Primary and secondary contaminants
- Greenhouse gases
- Clean Air Act

ENV.ER.3: Water and water pollution

- Potable water and water quality
- Hypoxia, eutrophication
- Clean Water Act
- Point source and non-point source contamination

ENV.ER.4: Soil and land

- Desertification
- Mass movement and erosion
- Sediment contamination
- Land use and land management (including food production, agriculture and zoning)
- Solid and hazardous waste

ENV.ER.5: Wildlife and wilderness

- Wildlife and wilderness management
    - Endangered species
- Invasive Species
- Introduced Species

CONTENT ELABORATION: EARTH'S RESOURCES

This topic explores the availability of Earth's resources, extraction of the resources, contamination problems, remediation techniques and the storage/disposal of the resources or by-products. Conservation, protection and sustainability of Earth's resources are also included. This builds on energy and Earth's resources topics in grades 6-8 and chemistry and energy topics at the high school level.

To understand the effects that certain contaminants may have on the environment, scientific investigations and research should be conducted on a local, national and global level. Water, air, land and biotic field and lab sampling/testing equipment and methods are utilized with real-world application. Quantifiable field and/or lab data are used to analyze and draw conclusions regarding air, water or land quality. Examples of types of water-quality testing include: hydraulic conductivity, suspended and dissolved solids, dissolved oxygen, biochemical oxygen demand, temperature, pH, fecal coliform and macro-invertebrate studies. Wetland or woodland delineations and analysis, land use analysis and air monitoring (e.g., particulate matter sizes/amount) are all appropriate field study investigations. Comparative analysis of scientific field or lab data should be used to quantify the environmental quality or conditions. Local data can also be compared to national and international data.

The study of relevant, local problems can be a way to connect the classroom to the real world. Within Ohio, there are numerous environmental topics that can be investigated. Examples include wetland loss or mitigation, surface or ground water contamination (including sediment, chemical or thermal contamination), watershed management, acid rain, septic system or sewage overflows/failures, landfill seepage, underground storage tank/pipe releases, deforestation, invasive species, air pollution (e.g., photochemical smog or particulate matter), soil loss/erosion or acid mine drainage.

At the advanced science level, renewable and nonrenewable energy resources topics investigate the effectiveness, risk and efficiency for differing types of energy resources at a local, state, national and global level. This builds upon grades 6-8 Earth and space science and physical science at the high school level. Nuclear and geothermal energy are included in this topic.

Feasibility, availability, remediation and environmental cost are included in the extraction, storage, use and disposal of both abiotic and biotic resources. Environmental impact is evaluated as it pertains to both environmental and human risks. Examples include chemical hazards, radiation, biological hazards, toxicology and risk analysis studies. Learning about conservation and protection of the environment also requires an understanding of the existence and rationale for laws and regulations to conserve resources and reduce and/or remediate contamination, but the emphasis should be on the science behind the laws and regulations.

Relating Earth's resources to a global scale and using technology to collect global resource data for comparative classroom study is recommended. In addition, it is important to connect the industry and the scientific community to the classroom to increase the depth of understanding. Critical thinking and problem-solving skills are important in evaluating resource use, management and conservation. New discoveries and research are important parts of this topic.

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
ENV.ER.1: Energy resources			
Design an energy efficient, clean, renewable community based upon real data and models of other cities or communities. Include explanations of the benefits and consequences of various aspects of the city design. Using existing energy technologies (e.g., tidal power plants, solar panels, scrubbers) as an example, generate an alternative way to collect energy or improve an existing energy technology. Test your design.	Contact your local energy provider and conduct an energy audit of your school. Identify areas where energy can be conserved. Generate a plan to decrease energy footprint. Record energy usage in your home for a 24 to 48-hour period. With parental permission, review an electric bill for your home and identify adoptable strategies to reduce your home's energy usage.	Compose a letter to a local politician or school board outlining the need for renewable/alternative energy exploration and incorporation into your city. Include information about taxes, resources and infrastructure. Compare energy usage of the United States to energy usage of a developing nation. Parse it down to a "typical" family in America and a "typical" family in the developing country. Create a public service announcement explaining the importance of energy conservation in your community, home and school. Include methods for conservation.	Identify the primary resources used in your community for energy. Create a brochure explaining and comparing the sources. Research a widely used energy source (e.g., nuclear, oil, gas, wind, solar) and create a detailed poster discussing the pros and cons of its use.
ENV.ER.2: Air and air pollution			
Design a "city makeover" for a city near you. Your new city must promote clean air practices. Consider mass transit, industry, infrastructure, homes, education and technology.	Conduct tests for air quality in and around your school, investigate the sources of any pollutants and design a plan to remove or reduce the pollutants.	Construct a model of your home or school explaining the internal air pollutants. Determine the relationships between the pollutants and human activities in or near your home/school. Looking at air quality data (e.g., from the US EPA) outline a plan for Ohio or the Great Lake States to improve air in the next seven years. Using ice core models and/or datasets, make a graph showing how elements in the atmosphere can change over time. Interpret and extrapolate into the future.	Create a presentation on the major types and sources of air pollution. Compare the main types and illustrate ways to prevent air pollution. Design and create a poster/graphic organizer/infographic illustrating the difference between primary and secondary contaminants. Read the Clean Air Act and create a timeline demonstrating major events that led up to it and major events which occurred after it. Include results of those events.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		Using the Clean Air Act as an example, propose an updated policy for the next 20 years, being sure to consider technology and demographics.	
ENV.ER.3: Water and water pollution			
Design and build a water filter with commonly available materials for either wastewater or drinking water, taking into account cost and efficiency. Test the water filter, analyze the data collected and brainstorm ideas on how to improve the design.	Conduct a water quality field test of various local bodies of water, and determine how the results (e.g., dissolved oxygen content, phosphates, nitrates/nitrites, pH, fecal coliform) could impact aquatic ecosystems. Identify two waterways in your area, one in a developed area and another in a natural area. Use biotic indicators and chemical tests to determine if any differences exist. Explain your findings, including ways contaminants may have moved from area to area.	Examine and report on your town's or city's water delivery system. Include where your drinking water comes from and where your waste water goes. Perform a water assessment on your home or school. Outline a water conservation plan based on the assessment. Explain where water can be conserved. Model how small changes can have large effects. Read excerpts or summaries of Rachel Carson's *Silent Spring* and create scenarios which model the effects of toxins introduced into a water system. Examine the actions that resulted from the publication of this book. Research water as a resource. Identify areas of concern and classify various sources (e.g., fresh, salt, ground, surface, glacier). Read the Clean Water Act and propose an amendment to address increases in populations and changes to ecosystems.	

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
ENV.ER.4: Soil and land			
Create a plan to revitalize a brownfield site in one of the Great Lake States. Be sure to include an explanation of how it became a brownfield.	Conduct soil tests on various sites around the school or community. Determine an appropriate location for planting a community garden. Consider soil types, precipitation and yield.	Research current FDA laws pertaining to food safety for agriculture and write user-friendly versions of the laws for the public to access on the FDA website. Write a letter to a company which historically violated EPA laws outlining their violations and the impact on the environment. Deconstruct an area affected by a mass wasting, desertification or erosion event and write a detailed explanation with data. Write a "brief" for a law firm assigning responsibility for purposes of restitution and remediation.	Identify at least two examples of modern desertification. Choose one in the United States and one in another country.
ENV.ER.5: Wildlife and wilderness			
Evaluate current practices to conserve or recover native species that are currently endangered. Make assessments about the introduction of species. Identify ways that it boosts endangered species populations and potential negative impacts. Design a plan to preserve/conserve a wilderness or waterway in Ohio. Be specific and defend your rationale with data. Include biological and ecological relationships within the system.		Choose a specific living species. Using scientific data, trace the history of that species. Show existing, established evolutionary relationships, environmental (both biotic and abiotic) requirements, global locations, ecosystem characteristics and sustainability predictions. Use quantifiable data to support findings. Write a bill to be presented to state policy makers restricting, preventing or eliminating an invasive species in Ohio. Compare the biodiversity of two natural areas, including richness and distribution. Draw conclusions, including how the biodiversity is relevant toward mitigating the impact of invasive species.	Research an Ohio wilderness or water ecosystem. Identify threats to each species, including human impacts. Discuss the process of biomagnification and the ramifications if a primary consumer or a producer is removed or too many consumers or producers are introduced. Create a presentation for local stakeholders on the hazards of invasive species. Identify invasive species in the community and describe their impacts on the local food web.

Environmental Science continued

ENV.GP: GLOBAL ENVIRONMENTAL PROBLEMS AND ISSUES
ENV.GP.1: Human population
ENV.GP.2: Potable water quality, use and availability
ENV.GP.3: Climate change
ENV.GP.4: Sustainability
ENV.GP.5: Species depletion and extinction
ENV.GP.6: Air quality
ENV.GP.7: Food production and availability
ENV.GP.8: Deforestation and loss of biodiversity
ENV.GP.9: Waste management (solid and hazardous)

CONTENT ELABORATION: GLOBAL ENVIRONMENTAL PROBLEMS AND ISSUES

This topic is a culminating section that incorporates the previous topics and applies them to a global or international scale. Case studies, developing and using models, collecting and analyzing water and/or air quality data, conducting or researching population studies and methods of connecting to the real world is emphasized for this topic. Technology can be used for comparative studies to share local data internationally so that specific quantifiable data can be compared and used in understanding the impact of some of the environmental problems that exist on a global scale. Researching and investigating environmental factors on a global level contributes to the depth of understanding by applying the environmental science concepts to problem solving and design. Examples of global topics that can be explored include building water or air filtration models, investigating climate change data, monitoring endangered, introduced or invasive species and studying the environmental effects of an increasing human population. Researching contemporary discoveries, new technology and new discoveries can lead to improvement in environmental management.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
ENV.GP.1: Human population			
Work in design teams to create a plan to develop a parcel of undeveloped rural land or to revitalize an urban neighborhood that has been blighted. Solutions must address housing, transportation, business and industrial, green space and recreational land uses as well as food, water, waste and energy systems. An extension could limit funds available.	Plan and implement a population study of a specific area over a period of time or critique/analyze an existing population study. Document changes in weather, food availability and any change to the population. Prepare a scientific analysis and conclusion (in writing) for the study. Use data on birth rates, death rates, life expectancy, average income and literacy rates of various countries[1] to develop a plan that could contribute to a change in the fertility and death rates.	Interpret population demographic curves, graphs or pyramids (e.g., from US Census Bureau, the UN Census, World Fact Book) and discuss differences in population growth rates among several different countries (developing vs. developed). Compare local fertility rates to national and international rates. Consider environmental and societal factors contributing to differences. Relative to resource availability and rates of consumption, assess the scope of human population growth and potential limits to its growth (e.g., Tragedy of the Commons, Hans Rosling and Gapminder Foundation)	Compare developing and developed countries, identifying the factors that separate the two types of countries.
ENV.GP.2: Potable water quality, use, and availability			
Design a water treatment system or process that can be implemented at a low cost and without the need for electricity to be used in areas that do not have access to potable water. Design and build an irrigation system that will move water at a specific rate.	Using data, research a severe water related environmental problem (and its root causes) that faces the local community, Ohio, the United States or the world. Propose ways to mitigate the problem. Test a local water source for contaminants and compare findings to the released water quality reports. If discrepancies exist, predict possible causes.	Investigate the source of various bottled water. Some brands come from municipal water supplies. Record each water source on a map. Examine the water quality report from a municipality to determine the health of the water. Investigate the effects of disinfection byproducts (DBPs) which result when chlorine and other disinfectants breakdown over time. Investigate sources of drinking water pollutants and design a plan to lower, restrict or prevent those pollutants. Conduct a water survey in your home/school. How much water do you use on a daily basis and how	Define potable water. Identify the locations of large sources of freshwater in the world and use this to explain why certain populations have little access to clean water.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		much does it cost? Identify areas where water can be saved.	

[1]Unicef data

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
ENV.GP.3: Climate change			
	Choose a specific location in the United States. Research and analyze the patterns of climate change throughout the geologic record, human historical data and present-day data for the location. Be able to explain the interpretation and analysis of the data. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.	Research monthly average precipitation data in different areas to strengthen conclusions about periods of drought or abnormal rainfall as they relate to climate change. Compare the effects of El Niño and La Niña at two different longitudinal locations, but at the same latitude, using sea surface temperature and precipitation from real satellite data. Create a timeline of climate science and policy initiatives over the past two centuries in developing and non-developing countries. Include global data and compare different nations. Investigate the history of local habitats experiencing change (e.g., the Great Lakes). Develop position papers for and against increasing federal spending on climate change research.	Explain the correlation between historical carbon dioxide concentration data and historical global temperature data.
ENV.GP.4: Sustainability			
Redesign a city/village/town to be more sustainable. Examine concepts such as waste treatment, water resources, pollution, transportation, energy resources and maintaining biodiversity. Share recommendations and incorporate feedback to make a final proposal for the city/village/town. Research and design a sustainable lifestyle in regard to energy efficient living space and mindfully using resources, alternative transportation, dietary sources and outdoor space.		Create a pie chart displaying the breakdown of components of an individual's ecological footprint (e.g., shelter, food, energy, transportation), and construct a plan to reduce his/her carbon footprint.	Use an online ecological footprint calculator (e.g., Earth Day Network) to compare how many Earths it would take to sustain the world population for various lifestyles. Use the Tragedy of the Commons simulation activity to identify and explain potential strategies to prevent the destruction of a common resource.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
ENV.GP.5: Species depletion and extinction			
Analyze a conservation case study (e.g., osprey, bald eagle, black bears in Ohio) and write an analysis and a recommendation for solutions. Using phenological protocols, collect information on the local plants and wildlife as the seasons progress and contribute data to a local or global study. Track for comparison from year to year and location to location. Identify trends in phenological changes and design solutions to local climate impacts.		Research the effect that climate change is having or has had on a specific living or extinct species (e.g., harp seal, polar bear, dinosaur, elkhorn coral) or on an ecosystem (e.g., the Great Barrier Reef, the Arctic Circle). Create an infographic on an endangered species, including information on the organism's ecosystem and its role within the ecosystem, its value (ecologically and commercially), reasons for endangerment and possible solutions or interventions. The National Audubon Society has been collecting data on avian population and movements for over a century through the annual Christmas Bird Count. Download a dataset of the history of birds for your locality and investigate trends in the status of populations.	Research the requirements for listing a species as a species of concern, threatened or endangered on the state or federal level. Identify a species on one of these lists and research its life history, specifically the impacts leading to its decline.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
ENV.GP.6: Air quality			
Design and construct a scrubber for cleaning the sulfur emissions from burning coal. Assess how well the scrubber works by collecting calcium sulfate or sulfite to compare against a control. Identify a problem or issue with air quality in your school/community. Use real data from the EPA and develop a solution.	Investigate the effects of acid rain (with a range of pH) on seed sprouting. Conduct an investigation comparing the concentration of tropospheric ozone in various locations in the community and analyze the results to determine the cause(s) for the any differences in concentrations.	Use a case study for a city that has historically experienced air pollution (e.g., Beijing, Detroit). Analyze the situation and identify issues/actions described in the case which may be problematic. Using real-time data, research air pollution issues (and the root causes for the problems) that face the local community, Ohio, the United States or the world. Present evidence (quantitative data) and conclusions orally, through a poster session or in written form (scientific research paper).	Illustrate the process of how acid rain is created and describe its effects on each component of the environment. Identify indoor pollutants and their sources. Explain their impacts.
ENV.GP.7: Food production and availability			
Identify the locations of food deserts in your community or surrounding areas. Write a proposal to the local government to provide that community with better food resources. Construct a plan for a sustainable garden that could provide food for your school/community. Share your plan with stakeholders.	Design and conduct an investigation to determine if a fertilizer or pesticide is toxic to an organism (e.g., radish seeds). Research food production in developing and underdeveloped nations, comparing land use vs. crop yield. Present your findings.	Research Genetically Modified Organisms used in agriculture and discuss advantages and disadvantages. Construct an energy pyramid (with a human at the top) and use data to defend or oppose the position that eating lower on the food chain is better for the environment. Using the National Geographic Website, *What the World Eats*, explore and compare the pie graphs to determine which country consumes the most/least daily calories, the most/least grains, the most/least meat, etc.	

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
ENV.GP.8: Deforestation and loss of biodiversity			
Design a community of the future that demonstrates responsible practices for preservation of biodiversity and forested areas.	Use satellite mapping resources (NASA Forest Changes in Rondonia, Brazil) to investigate the connection between urbanization, population growth and deforestation. Summarize your findings.	Write a proposal for the state setting limits/regulations for housing/commercial development through the lens of biodiversity. Consider federal laws. Develop a PSA on commercial products that contribute to deforestation (e.g., palm oil) and how deforestation contributes to the loss of biodiversity. Engage in a classroom discussion on the rationale and methods to reduce the deer population in an Ohio community. Complete a graphic organizer on various tree harvesting practices (e.g., clear cutting, seed tree cutting, selective cutting, slash & burn) including a description of economic and ecological advantages and disadvantages of each.	Identify areas where urban sprawl has impacted plant, wildlife and human communities. Describe the effects on biodiversity.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
ENV.GP.9: Waste management (solid and hazardous)			
Develop a risk assessment for humans or the environment due to a toxin or hazardous chemical used by a company. The assessment should include: nature of the toxin/chemical, on-site use and handling (including existing safety practices), by-products (e.g., vapors, dilution processes), storage, transportation and emergency plans. Consider the topography and geology of the area and how these contribute to the flow of spills or leaks. Use a computer-modeling program (many are available through freeware sites) to model and predict the movement and possible pathways of the toxin/chemical. Make recommendations for containment methods. Research composting techniques. Analyze the wastes produced by the school and design an appropriate composting system to process the biodegradable waste produced. Construct and maintain a composting site on school grounds.	Conduct a landfill decomposition study over an extended period to determine the rate at which typical materials found in landfills decompose.	Collect research information on various waste management types. Compare and contrast the practices of waste management of developed and developing nations. Compare methods of at least two different nations and identify the best practices. Research the waste management issues and the root causes for the problems that face the local community, Ohio, the United States or the world. Plan and implement an investigation to explore human health issues related to the disposal of hazardous waste materials (e.g., biomagnification or bioaccumulation within a specific Ohio ecosystem). Existing public case studies can be used, such as a local Brownfields case.	Document the amount of waste a family/individual produces throughout a 24-hour period. Identify the materials that are non-recyclable and recyclable. Describe the benefits and challenges of recycling. Draw a diagram of a modern landfill and label the various components that are required or used in landfills today to prevent them from polluting the air and water.

Physical Geology

INTRODUCTION AND SYLLABUS

COURSE DESCRIPTION

Physical Geology is a high school level course, which satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires three units of science. Each course should include inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.

Physical geology incorporates chemistry, physics and environmental science and introduces students to key concepts, principles and theories within geology. Investigations are used to understand and explain the behavior of nature in a variety of inquiry and design scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications.

COURSE CONTENT

The following information may be taught in any order; there is no ODE-recommended sequence.

PG.M: MINERALS

PG.M.1: Atoms and elements
PG.M.2: Chemical bonding (ionic, covalent, metallic)
PG.M.3: Crystallinity (crystal structure)
PG.M.4: Criteria of a mineral (crystalline solid, occurs in nature, inorganic, defined chemical composition)
PG.M.5: Properties of minerals (hardness, luster, cleavage, streak, crystal shape, fluorescence, flammability, density/specific gravity, malleability)

PG.IMS: IGNEOUS, METAMORPHIC AND SEDIMENTARY ROCKS

PG.IMS.1: Igneous

- Mafic and felsic rocks and minerals
- Intrusive (igneous structures: dikes, sills, batholiths, pegmatites)
- Earth's interior (inner core, outer core, lower mantle, upper mantle, Mohorovicic discontinuity, crust)
- Magnetic reversals and Earth's magnetic field
- Thermal energy within the Earth
- Extrusive (volcanic activity, volcanoes: cinder cones, composite, shield)
- Bowen's Reaction Series (continuous and discontinuous branches)

PG.IMS.2: Metamorphic

- Pressure, stress, temperature and compressional forces
- Foliated (regional), non-foliated (contact)
- Parent rock and degrees of metamorphism
- Metamorphic zones (where metamorphic rocks are found)

PG.IMS.3: Sedimentary

- Division of sedimentary rocks and minerals (chemical, clastic/physical, organic)
- Depositional environments

PG.IMS.4: Ocean

- Tides (daily, neap and spring)
- Currents (deep and shallow, rip and longshore)
- Thermal energy and water density
- Waves
- Ocean features (ridges, trenches, island systems, abyssal zone, shelves, slopes, reefs, island arcs)
- Passive and active continental margins
- Transgressing and regressing sea levels
- Streams (channels, streambeds, floodplains, cross-bedding, alluvial fans, deltas)

PG.EH: EARTH'S HISTORY

PG.EH.1: The geologic rock record

- Relative and absolute age
- Principles to determine relative age
  - Original horizontality
  - Superposition
  - Cross-cutting relationships
- Absolute age
  - Radiometric dating (isotopes, radioactive decay)
  - Correct uses of radiometric dating
- Combining relative and absolute age data
- The geologic time scale
  - Comprehending geologic time
  - Climate changes evident through the rock record
  - Fossil record

PG.PT: PLATE TECTONICS

PG.PT.1: Internal Earth
- Seismic waves
  - S and P waves
  - Velocities, reflection, refraction of waves

PG.PT.2: Structure of Earth (Note: specific layers were part of grade 8)
- Asthenosphere
- Lithosphere
- Mohorovicic boundary (Moho)
- Composition of each of the layers of Earth
- Gravity, magnetism and isostasy
- Thermal energy (geothermal gradient and heat flow)

PG.PT.3: Historical review (Note: this would include a review of continental drift and seafloor spreading found in grade 8)
- Paleomagnetism and magnetic anomalies
- Paleoclimatology

PG.PT.4: Plate motion (Note: introduced in grade 8)
- Causes and evidence of plate motion
- Measuring plate motion
- Characteristics of oceanic and continental plates
- Relationship of plate movement and geologic events
- Mantle plumes

PG.ER: EARTH'S RESOURCES

PG.ER.1: Energy resources
- Renewable and nonrenewable energy sources and efficiency
- Alternate energy sources and efficiency
- Resource availability
- Mining and resource extraction

PG.ER.2: Air
- Primary and secondary contaminants
- Greenhouse gases

PG.ER.3: Water
- Potable water and water quality
- Hypoxia, eutrophication

PG.ER.4: Soil and sediment
- Desertification
- Mass wasting and erosion
- Sediment and contamination

PG.GG: GLACIAL GEOLOGY

PG.GG.1: Glaciers and glaciation
- Evidence of past glaciers (including features formed through erosion or deposition)
- Glacial deposition and erosion (including features formed through erosion or deposition)
- Data from ice cores
  - Historical changes (glacial ages, amounts, locations, particulate matter, correlation to fossil evidence)
  - Evidence of climate changes throughout Earth's history
- Glacial distribution and causes of glaciation
- Types of glaciers – continental (ice sheets, ice caps), alpine/valley (piedmont, valley, cirque, ice caps)
- Glacial structure, formation and movement

NATURE OF SCIENCE HIGH SCHOOL

Nature of Science
One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.

Categories	High School
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Identify questions and concepts that guide scientific investigations. • Design and conduct scientific investigations using a variety of methods and tools to collect empirical evidence, observing appropriate safety techniques. • Use technology and mathematics to improve investigations and communications. • Formulate and revise explanations and models using logic and scientific evidence (critical thinking). • Recognize and analyze explanations and models. • Communicate and support scientific arguments.

Science is a Way of Knowing
Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.
	• Various science disciplines use diverse methods to obtain evidence and do not always use the same set of procedures to obtain and analyze data (i.e., there is no one scientific method).
	  o Make observations and look for patterns.
	  o Determine relevant independent variables affecting observed patterns.
	  o Manipulate an independent variable to affect a dependent variable.
	  o Conduct an experiment with controlled variables based on a question or hypothesis.
	  o Analyze data graphically and mathematically.
	• Science disciplines share common rules of evidence used to evaluate explanations about natural phenomenon by using empirical standards, logical arguments and peer reviews.
	  o Empirical standards include objectivity, reproducibility, and honest and ethical reporting of findings.
	  o Logical arguments should be evaluated with open-mindedness, objectivity and skepticism.
	• Science arguments are strengthened by multiple lines of evidence supporting a single explanation.
	• The various scientific disciplines have practices, methods, and modes of thinking that are used in the process of developing new science knowledge and critiquing existing knowledge.

Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• Science depends on curiosity, imagination, creativity and persistence. • Individuals from different social, cultural, and ethnic backgrounds work as scientists and engineers. • Science and engineering are influenced by technological advances and society; technological advances and society are influenced by science and engineering. • Science and technology might raise ethical, social and cultural issues for which science, by itself, does not provide answers and solutions.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• Science can advance through critical thinking about existing evidence. • Science includes the process of comparing patterns of evidence with current theory. • Some science knowledge pertains to probabilities or tendencies. • Science should carefully consider and evaluate anomalies (persistent outliers) in data and evidence. • Improvements in technology allow us to gather new scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Physical Geology continued

PG.M: MINERALS
PG.M.1: Atoms and elements
PG.M.2: Chemical bonding (ionic, covalent, metallic)
PG.M.3: Crystallinity (crystal structure)
PG.M.4: Criteria of a mineral (crystalline solid, occurs in nature, inorganic, defined chemical composition)
PG.M.5: Properties of minerals (hardness, luster, cleavage, streak, crystal shape, fluorescence, flammability, density/specific gravity, malleability)

CONTENT ELABORATION: MINERALS

This unit builds upon the Earth and Space Science strand in grade 6, where common minerals are defined, tested and classified. It also incorporates knowledge of mineral properties and crystalline structures (chemical compositions and bonding) included in the chemistry sections of other high school courses.

The emphasis in this course is to relate the chemical and physical components of minerals to the properties of the minerals. This requires extensive mineral testing, investigations, experimentation, observation, use of technology and models/modeling. The focus is on learning the ways to research, test and evaluate minerals, not in memorization of mineral names or types.

Properties such as cleavage and hardness are connected to the chemical structure and bonding of the mineral. In addition, the environment in which minerals form should be part of the classification of the mineral, using mineral data to help interpret the environmental conditions that existed during the formation of the mineral.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PG.M.1: Atoms and elements			
Evaluate the appropriateness of extracting minerals such as uranium, platinum, copper, phosphorus, aluminum, sodium or iron in populated areas.	Develop a system to recycle used minerals from a product (e.g., tin cans, aluminum foil, copper pipes).	Explain how crystalline structure relates to a mineral's properties as well as its use and application in daily life. Represent the chemical compositions of common minerals with a drawing and/or 3D model. Explain what is represented in the depiction of the chemical formula.	Classify the groups of minerals by chemical composition. Compare minerals and ores and identify their uses. Given a chemical formula for a mineral, identify the elemental composition and relate this to its properties.
PG.M.2: Chemical bonding (ionic, covalent, metallic)			
		Conduct tests to differentiate between ionically and covalently bonded materials. Design a 3-D model of the different types of chemical bonding.	Identify types of bonds present in each mineral group/family.
PG.M.3: Crystallinity (crystal structure)			
		Explain why specific crystalline structures are different from each other. Use crystal or atomic models to illustrate the crystal structure of common minerals. Relate the structure to a specific quantifiable property (e.g., cleavage, hardness).	Categorize crystalline shapes (7) and list what minerals would be found in each category.
PG.M.4: Criteria of a mineral (crystalline solid, occurs in nature, inorganic, defined chemical composition)			
Design a method to use GIS to target mineral exploration or evaluate mining conditions and extraction methods. Then, construct a model of a site which has minimal environmental impact.	Plan and conduct an investigation to determine the specific gravity of minerals.	Construct a graphic model depicting how minerals are classified into groups by chemical composition and crystal formation. Create an atom building game that demonstrates how elements combine to build minerals.	Identify and classify a mineral based on tested properties. Use a variety of rock samples to identify the minerals present. Examine mineral samples for crystalline structure and cleavage/fracture.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PG.M.5: Properties of minerals (hardness, luster, cleavage, streak, crystal shape, fluorescence, flammability, density/specific gravity, malleability)			
Research social issues relating to conflict minerals (e.g., coltan, tungsten, gold). Determine whether there are alternative sources for these minerals.	Develop a method to determine the difference between pyrite and gold using tools available to early gold prospectors.	Determine the best use of a mineral based on observable properties. Select a consumer product. Determine the minerals used in the product and the reason(s) for their use.	Differentiate between cleavage and fracture. Test a mineral for hardness (Mohs Scale), malleability and streak.

Physical Geology continued

PG.IMS: IGNEOUS, METAMORPHIC AND SEDIMENTARY ROCKS

PG.IMS.1: Igneous

- Mafic and felsic rocks and minerals
- Intrusive (igneous structures: dikes, sills, batholiths, pegmatites)
- Earth's interior (inner core, outer core, lower mantle, upper mantle, Mohorovičić discontinuity, crust)
- Magnetic reversals and Earth's magnetic field
- Thermal energy within Earth
- Extrusive (volcanic activity, volcanoes: cinder cones, composite, shield)
- Bowen's Reaction Series (continuous and discontinuous branches)

PG.IMS.2: Metamorphic

- Pressure, stress, temperature and compressional forces
- Foliated (regional), non-foliated (contact)
- Parent rock and degrees of metamorphism
- Metamorphic zones (where metamorphic rocks are found)

PG.IMS.3: Sedimentary

- Division of sedimentary rocks and minerals (chemical, clastic/physical, organic)
- Depositional environments

PG.IMS.4: Ocean

- Tides (daily, neap and spring)
- Currents (deep and shallow, rip and longshore)
- Thermal energy and water density
- Waves
- Ocean features (ridges, trenches, island systems, abyssal zone, shelves, slopes, reefs, island arcs)
- Passive and active continental margins
- Transgressing and regressing sea levels
- Streams (channels, streambeds, floodplains, cross-bedding, alluvial fans, deltas)

CONTENT ELABORATION: IGNEOUS, METAMORPHIC AND SEDIMENTARY ROCKS

This unit builds upon a variety of topics studied in middle school. In the Earth and Space Science strand, sedimentary, igneous and metamorphic rocks are introduced. Rocks and minerals are tested and classified. Plate tectonics, seismic waves and the structure of Earth are studied and the geologic record is introduced (including the evidence of climatic variances through Earth's history). In the Life Science strand, fossils and depositional environments are included as they relate to the documented history of life in the geologic record. In the Physical Science strand, waves, thermal energy, currents, pressure and gravity are presented.

In this course, geologic, topographic, seismic and aerial maps are used to locate and recognize igneous, metamorphic and sedimentary structures and features. Technological advances permit the investigation of intrusive structures and the interior of Earth. Connections between the minerals present within each type of rock and the environment formed are important. The processes and environmental conditions that lead to fossil fuel formation (**Note:** *this links to the energy resources section below*) includes the fossil fuels found in Ohio, nationally and globally.

Bowen's Reaction Series is used to develop an understanding of the relationship of cooling temperature, formation of specific igneous minerals and the resulting igneous environment. The focus is on knowing how to use Bowen's Reaction Series, not to memorize it. Virtual demonstrations and simulations of cooling magma and crystallization of the igneous minerals found on the series can be helpful in conceptualizing the chart.

The magnetic properties of Earth are examined through the study of real data and evidence. The relationship of polar changes, magnetic striping, grid north, true north and the North Pole are included in the study of Earth's magnetic properties.

Features found in the ocean include all types of environments (igneous, metamorphic or sedimentary). Using models (3-D or virtual) with real-time data to simulate waves, tides, currents, feature formation and changing sea levels to explore and investigate the ocean fully is recommended. Interpreting sections of the geologic record to determine sea level changes and depositional environments, including relative age, is also recommended.

Technological advances can be used to observe and record the physical features of the Earth, including the ocean floor. Interpreting geologic history using maps of local cross-sections of bedrock can be related to the geologic history of Ohio, the United States and Earth.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	PG.IMS.1: Igneous		
Determine the feasibility of building a tunnel or road in a specific location based on the type of rocks present.		Create a dichotomous key allowing for the identification of various igneous rocks. Use Bowen's reaction series to identify the origins of several rocks. Provide evidence to support the identification.	Identify characteristics of different classifications of igneous, metamorphic, and sedimentary rocks.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PG.IMS.2: Metamorphic			
Create a building construction task based on student criteria. Analyze the pros and cons of different rock types to determine the most appropriate rock(s) for various aspects of the project.		Create a dichotomous key allowing for the identification of various metamorphic rocks.	Sort metamorphic rocks by the grade of metamorphism. Describe the conditions under which various metamorphic rocks were formed from parent material.
PG.IMS.3: Sedimentary			
Design a mining method (large or small scale) that allows material to be removed without collapse.	Evaluate the ability of various sedimentary rocks to transport fluids (e.g., groundwater, oil, natural gas).	Create a dichotomous key allowing for the identification of various sedimentary rocks. Use fossils found in sedimentary rock to determine changes in sea level over geological time.	Identify and classify sedimentary rocks based on characteristics. Describe the depositional environment for various samples of sedimentary rocks.
PG.IMS.4: Ocean			
Design and engineer a method to use ocean waves, tides or currents to produce energy. Research historic changes in the course of the Mississippi River. Discuss the pros and cons of the engineering methods being used to maintain its current course.		Trace the development of an El Niño or La Niña event and explain how thermal energy shifts alter local and regional conditions. Analyze why the Colorado River no longer flows into the Sea of Cortez. Use aerial photos over the last century to explain what happened to the delta. Analyze how neap and spring tides impact coastal regions, especially during storm events and other natural occurrences.	Identify the various features around and within a stream system using Google Earth. Map major ocean currents and identify various types of currents. Map major trenches, ridges and island systems in each ocean.

Physical Geology continued

PG.EH: EARTH'S HISTORY
PG.EH.1: The geologic rock record

- Relative and absolute age
- Principles to determine relative age
    - Original horizontality
    - Superposition
    - Cross-cutting relationships
- Absolute age
    - Radiometric dating (isotopes, radioactive decay)
    - Correct uses of radiometric dating
- Combining relative and absolute age data
- The geologic time scale
    - Comprehending geologic time
    - Climate changes evident through the rock record
    - Fossil record

CONTENT ELABORATION: EARTH'S HISTORY

This unit builds upon a variety of topics studied in middle school. In the Earth and Space Science strand, sedimentary, igneous and metamorphic rocks are introduced. Rocks and minerals are tested and classified. Plate tectonics, seismic waves and the structure of Earth are studied and the geologic record is explored (including uniformitarianism, superposition, cross-cutting relationships and the evidence of climatic variances through Earth's history). In the Life Science strand, fossils and depositional environments are included as they relate to the documented history of life in the geologic record. In the Physical Science strand, radiometric dating, seismic waves, thermal energy, pressure and gravity are presented.

In this course, the long-term history of Earth and the analysis of the evidence from the geologic record (including fossil evidence) are investigated.

Using actual sections of the geologic record to interpret, compare and analyze can demonstrate the changes that have occurred in Ohio, in North America and globally. The emphasis for this unit is to explore the geologic record and the immensity of the geologic record. The analysis of data and evidence found in the variety of dating techniques (both absolute and relative), the complexity of the fossil record, and the impact that improving technology has had on the interpretation and continued updating of what is known about the history of Earth are investigated. Geologic principles are essential in developing this level of knowledge. These principles can be tested and experienced virtually, or through modeling, field studies, research and in-depth investigations.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PG.EH.1: The geologic rock record			
	Design and conduct a field study in a local area to locate fossil evidence that can be combined with other rock evidence to interpret the geologic history of the area. Document the fieldwork and steps of the investigation. Present an analysis of the data and the interpretation of the geologic history.	Use a geologic cross-section (or conduct a field investigation) for a specific location to analyze/interpret geologic history (e.g., rock type, formation, fossils or minerals present) and environmental conditions (e.g., volcanic activity, transgressing and regressing sea levels). Use evidence (e.g., glacial maps) to describe climate changes which occurred in Ohio. Develop a 3D model that shows the geologic layers of the local area using data published by scientists. Research the glacial history of a specific location using data from the rock record, contemporary field data (research conducted and published by scientists) and/or glacial features that can be documented (e.g., maps, virtual aerial documentation, remote sensing data). Relate the history to contemporary evidence of changing climate. Examine a glacial map of Ohio to compare the northern counties with the southern counties. What features would you expect to find in each location? Explain why there could be differences in the absolute age determination of rock when different isotopes are used.	Describe fossils that are common to the local area and relate them to the geologic history of that region of Ohio. Explain how absolute age is determined using different radioactive isotopes. Select which isotopes would be best for dating rock in a particular location (e.g., bottom of Grand Canyon, rocks in a dinosaur dig). Describe the different divisions of geologic history and what specific events can be found within each division.

Physical Geology continued

PG.PT: PLATE TECTONICS

PG.PT.1: Internal Earth

- Seismic waves
  - S and P waves
  - Velocities, reflection, refraction of waves

PG.PT.2: Structure of Earth

- Asthenosphere
- Lithosphere
- Mohorovičić boundary (Moho)
- Composition of each of the layers of Earth
- Gravity, magnetism and isostasy
- Thermal energy (geothermal gradient and heat flow)

PG.PT.3: Historical review

- Paleomagnetism and magnetic anomalies
- Paleoclimatology

PG.PT.4: Plate motion

- Causes and evidence of plate motion
- Measuring plate motion
- Characteristics of oceanic and continental plates
- Relationship of plate movement and geologic events and features
- Mantle plumes

CONTENT ELABORATION: PLATE TECTONICS

This unit builds upon a variety of topics studied in middle school. In the Earth and Space Science strand, plate tectonics is studied in grade 8. Topics include plate motion (evidence and causes, characteristics of oceanic and continental plates), seismic waves, continental drift, seafloor spreading, the structure of Earth's surface and interior (including specific layers) and paleomagnetism. In the Life Science strand, fossils and depositional environments are included. In the Physical Science strand, density, convection, conductivity, motion, kinetic energy, radiometric dating, seismic waves, thermal energy, pressure and gravity are explored.

In this course, Earth's interior and plate tectonics are investigated at greater depth using models, simulations, actual seismic data, real-time data, satellite data and remote sensing. Relationships between energy, tectonic activity levels and earthquake or volcano predictions, and calculations to obtain the magnitude, focus and epicenter of an earthquake are included. Evidence and data analysis are key in understanding this part of the Earth system. For example, GIS/GPS and/or satellite data provide evidence for moving plates and changing landscapes (due to tectonic activity).

The causes for plate motion, the evidence of moving plates and the results of plate tectonics must be related to Earth's past, present and future. The use of evidence to support conclusions and predictions pertaining to plate motion is an important part of this unit.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PG.PT.1: Internal Earth			
Design model buildings to withstand earthquakes. Use shake tables to test the models. Refine designs based on test results. Compare designs within the class to evaluate to most effective design techniques.	Construct a three-dimensional model that illustrates plate subduction using earthquake foci depth data. Determine how an earthquake can cause the reversal of flow in a river using a project-based approach.	Determine the distance of an epicenter from a seismic station using travel time curves. Locate the epicenter of an earthquake by triangulation. Calculate the time of origin of an earthquake based on seismic data. Create a marketing pamphlet describing features of an earthquake resistant building/structure. Given earthquake and damage data (e.g., photos, reports, eyewitness accounts), rate each occurrence on the Mercalli scale. Create an approach for using this data to pinpoint the epicenter of the earthquake. Determine the rating of the earthquake on the Richter Scale using historic descriptions of earthquake occurrences.	Identify P, S, and surface waves on three-component seismograms. Identify the difference between reflection and refraction of seismic waves. Perform basic velocity calculations related to P and S wave speed.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		PG.PT.2: Structure of Earth	
Research a specific area with active geologic processes or events. Develop a plan to harness the available energy (e.g., heat from magma, water movement) from the process. Build a working model using specific data from the location. Evaluate the efficiency of the type of energy chosen.		Provide evidence to dispute the hypothesis that Earth is homogeneous throughout.	Explain how seismic wave behavior helps scientists determine where Earth's interior layers are located.
		PG.PT.3: Historical review	
		Use data to investigate the magnetic reversals and the resulting magnetic striping that occurs at oceanic ridges. Create a model demonstrating how paleomagnetic stripes on the seafloor provided clues to magnetic reversals of the planet. Create a seafloor profile using maps and depth charts to illustrate seafloor spreading. Create a chart or table using evidence from the rock record to document the pattern of climate change that has occurred throughout geologic time. Use scientific data to document periods of climate fluctuation. Evaluate patterns and cause and effect that may be evident in the research. Assemble a puzzle based on Pangaea and use it to explain the processes that separated Pangaea. Project future plate movement.	Explain the cause of seafloor spreading and continental drift.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		Evaluate various methods used to map and collect samples from the seafloor. Explain how ancient ice, pollen and tree ring samples provide evidence of ancient climate changes on Earth.	
G.PT.4: Plate motion			
		Identify specific geologic features using LANDSAT or other remote sensing data. Identify the factors required to create the specific features. Create a 3-D working model of a real landform created by plate tectonics (e.g., faults, fault block mountains, volcanoes, rift valleys). Create a digital bulletin board or a 360 Google Map tour of a geologic feature created by plate tectonics. Use isotopic, petrological and/or geochemical evidence to identify motion at plate boundaries. Research the most recent measurements of North America. Using this data and the movement of North America throughout geologic time, predict where North America will be in 600 million years or more. Create a model to demonstrate that movement.	Identify characteristics of oceanic and continental plates using data. Correlate locations of volcanoes and earthquakes with plate boundaries. Identify plate motion as a cause for construction and destruction of landforms and surface features on Earth's crust. Explain how heat transfer causes plate motion. Explain the causes and evidence of plate motion.

Physical Geology continued

PG.ER: EARTH'S RESOURCES

PG.ER.1: Energy resources

- Renewable and nonrenewable energy sources and efficiency
- Alternate energy sources and efficiency
- Resource availability
- Mining and resource extraction

PG.ER.2: Air

- Primary and secondary contaminants
- Greenhouse gases

PG.ER.3: Water

- Potable water and water quality
- Hypoxia, eutrophication

PG.ER.4: Soil and sediment

- Desertification
- Mass wasting and erosion
- Sediment contamination

CONTENT ELABORATION: EARTH'S RESOURCES

This unit builds upon a variety of topics studied in previous courses. In elementary school, renewable/nonrenewable energy, soils, the atmosphere and water are introduced. In middle school, Earth's spheres, Earth's resources and energy resources are explored. At the high school level, water, air, chemistry and energy topics are studied. In this course, the Earth Resources topic should be looked at through the lens of geology when referring to renewable/non-renewable resources, air, water, soil, and energy.

In this course, renewable and nonrenewable energy resources topics investigate the effectiveness and efficiency for differing types of energy resources at a local, state, national and global level. Feasibility, availability and environmental cost are included in the extraction, storage, use and disposal of both abiotic and biotic resources. Modeling (3-D or virtual), simulations and real-world data are used to investigate energy resources and exploration. The emphasis is on current, actual data, contemporary science and technological advances in the field of energy resources.

Relating Earth's resources (e.g., energy, air, water, soil) to a global scale and using technology to collect global resource data for comparative classroom study is recommended. In addition, it is important to connect industry and the scientific community to the classroom to increase the depth of understanding. Critical thinking and problem-solving skills are important in evaluating resource use and conservation.

Smaller scale investigations, such as a field study to monitor stream quality, construction mud issues, storm water management, nonpoint source contamination problems (e.g., road-salt runoff, agricultural runoff, parking lot runoff) or thermal water contamination, can be useful in developing a deeper understanding of Earth's resources.

Earth systems are used to illustrate the interconnectedness of each of Earth's spheres (hydrosphere, lithosphere, atmosphere and biosphere) and the relationship between each type of Earth's resources.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PG.ER.1: Energy resources			
Design and build (virtual, blueprint or 3-D model) an Eco-House that uses green technology and allows the house to be off-grid. Select a specific location and evaluate the different options that would be efficient and effective for that area.			Compare mineral uses versus availability and demand. Identify different energy resources as renewable and non-renewable.
PG.ER.2: Air			
Design a technology to remove either particulate or chemical pollutants from air. Collect samples of air to investigate a local contamination issue. Recommend ways to reduce or prevent contamination based on scientific data and research.	Determine the amount and size of particulate matter in the air at the school or community. Analyze the results using information from the Environmental Protection Agency and the Department of Health (e.g., lung diseases, including emphysema and asthma). Locate specific Ohio data for comparative analysis. Report class findings and recommendations orally or in written form to school administrators or community leaders. Survey the indoor school environment for the presence of ozone using Schoenbein's papers prepared in class.	Describe the components and processes involved in the generation of photochemical smog. Describe positive and negative feedback loops that impact the greenhouse effect and climate change.	Describe the characteristics of each layer of the atmosphere, including any benefits to or uses by humans. Describe how the atmosphere and the oceans interact to sequester atmospheric carbon.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PG.ER.3: Water			
Investigate different methods (e.g., aeration, filtration) for removing pollutants from water. Design, build and test water filters. Collect samples of water to investigate a local contamination issue. Recommend ways to reduce or prevent contamination based on scientific data and research.		Deconstruct the events leading up to a fish kill in a local river, given data including times, locations, and eye-witness accounts. Use topographic maps to decide on an area to locate wells or a reservoir for drinking water for a city.	
PG.ER.4: Soil and sediment			
Collect samples of soil to investigate a local contamination issue. Recommend ways to reduce or prevent contamination based on scientific data and research. Build a model construction site and use it to develop techniques to manage storm water runoff and construction mud.	Construct a model to explore how soil type (e.g., sand, silt, clay), water content and slope affect severity of landslides. Create a topographic, soil or geologic map of the school or community using actual data collected from the field (e.g., GPS/GIS readings, field investigation, aerial maps). Present a final map in a poster session, along with data used in the development of the map and an analysis of the data.	Describe the steps of desertification and identify areas on a globe that represent each of the transitions.	Identify types of mass wasting that are present in the local area.

Physical Geology continued

PG.GG: GLACIAL GEOLOGY
PG.GG.1: Glaciers and glaciation

- Evidence of past glaciers (including features formed through erosion or deposition)
- Glacial deposition and erosion (including features formed through erosion or deposition)
- Data from ice cores
  - Historical changes (glacial ages, amounts, locations, particulate matter, correlation to fossil evidence)
  - Evidence of climate changes throughout Earth's history
- Glacial distribution and causes of glaciation
- Types of glaciers – continental (ice sheets, ice caps), alpine/valley (piedmont, valley, cirque, ice caps)
- Glacial structure, formation and movement

CONTENT ELABORATION: GLACIAL GEOLOGY

This unit builds upon a variety of topics previously studied. In fourth grade, Earth's surface (landforms and features, including glacial geology) is introduced. In middle school, igneous, metamorphic and sedimentary rocks, sediment and soils, the geologic record and Earth's history are studied. The cryosphere and the relationship of the analysis of ice cores in understanding changes in climate over thousands of years is also introduced. Fossils and fossil evidence within the geologic record is found in the Life Science strand, building from second grade through high school biology.

An emphasis for this unit is tracing and tracking glacial history and present-day data for Ohio, the United States and globally. Scientific data found in the analysis of the geologic record, ice cores and surficial geology should be used to provide the evidence for changes that have occurred over the history of Earth and are observable in the present day. New discoveries, mapping projects, research, contemporary science and technological advances are included in the study of glacial geology. The focus should be on the geologic processes and the criteria for movement. Modeling and simulations (3-D or virtual) can be used to illustrate glacial movement and the resulting features.

Field investigations to map and document evidence of glaciers in the local area (if applicable) or virtual investigations can help demonstrate the resulting glacial features and the impact that ice has had on the surface of Earth throughout history. Real-time data (using remote sensing, satellite, GPS/GIS, aerial photographs/maps) can help support this topic.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
PG.GG.1: Glaciers and glaciation			
	Design an investigation to determine/evaluate how changes in slope, substrate and temperature affect glacial flow dynamics.	Use Google Earth to identify locations of features created by glaciers. Take or find pictures of the features and add them to Google Earth in the correct locations. Develop a model to reconstruct glacial history that includes resulting features (e.g., U-shaped valleys, moraines, tills, kettles, eskers, erratics, outwash). Use the model to explain the processes.	Recognize and identify different types of glaciers and glacial features using aerial photographs, LANDSAT data, surficial geology maps or topographic maps. Identify topographic features in Ohio and explain the geological processes involved in creating those features.

Physics

INTRODUCTION AND SYLLABUS

COURSE DESCRIPTION

Physics is a high school level course, which satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires three units of science. Each course should include inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.

Physics elaborates on the study of the key concepts of motion, forces and energy as they relate to increasingly complex systems and applications that will provide a foundation for further study in science and scientific literacy.

Students engage in investigations to understand and explain motion, forces and energy in a variety of inquiry and design scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications.

COURSE CONTENT

The following information may be taught in any order; there is no ODE-recommended sequence.

P.M: MOTION

P.M.1: Motion Graphs
- Position vs. time
- Velocity vs. time
- Acceleration vs. time

P.M.2: Problem Solving
- Using graphs (average velocity, instantaneous velocity, acceleration, displacement, change in velocity)
- Uniform acceleration including free fall (initial velocity, final velocity, time, displacement, acceleration, average velocity)

P.M.3: Projectile Motion
- Independence of horizontal and vertical motion
- Problem-solving involving horizontally launched projectiles

P.F: FORCES, MOMENTUM AND MOTION

P.F.1: Newton's laws applied to complex problems
P.F.2: Gravitational force and fields
P.F.3: Elastic forces
P.F.4: Friction force (static and kinetic)
P.F.5: Air resistance and drag
P.F.6: Forces in two dimensions
- Adding vector forces
- Motion down inclines
- Centripetal forces and circular motion

P.F.7: Momentum, impulse and conservation of momentum

P.E: ENERGY

P.E.1: Gravitational potential energy
P.E.2: Energy in springs
P.E.3: Work and power
P.E.4: Conservation of energy
P.E.5: Nuclear energy

P.W: WAVES

P.W.1: Wave properties
- Conservation of energy
- Reflection
- Refraction
- Interference
- Diffraction

P.W.2: Light phenomena
- Ray diagrams (propagation of light)
- Law of reflection (equal angles)
- Snell's law
- Diffraction patterns
- Wave—particle duality of light
- Visible spectrum of color

P.EM: ELECTRICITY AND MAGNETISM

P.EM.1: Charging objects (friction, contact and induction)
P.EM.2: Coulomb's law
P.EM.3: Electric fields and electric potential energy
P.EM.4: DC circuits

- Ohm's law
- Series circuits
- Parallel circuits
- Mixed circuits
- Applying conservation of charge and energy (junction and loop rules)

P.EM.5: Magnetic fields
P.EM.6: Electromagnetic interactions

NATURE OF SCIENCE HIGH SCHOOL

Nature of Science
One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.

Categories	High School
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Identify questions and concepts that guide scientific investigations. • Design and conduct scientific investigations using a variety of methods and tools to collect empirical evidence, observing appropriate safety techniques. • Use technology and mathematics to improve investigations and communications. • Formulate and revise explanations and models using logic and scientific evidence (critical thinking). • Recognize and analyze explanations and models. • Communicate and support scientific arguments.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	• Various science disciplines use diverse methods to obtain evidence and do not always use the same set of procedures to obtain and analyze data (i.e., there is no one scientific method). o Make observations and look for patterns. o Determine relevant independent variables affecting observed patterns. o Manipulate an independent variable to affect a dependent variable. o Conduct an experiment with controlled variables based on a question or hypothesis. o Analyze data graphically and mathematically. • Science disciplines share common rules of evidence used to evaluate explanations about natural phenomenon by using empirical standards, logical arguments and peer reviews. o Empirical standards include objectivity, reproducibility and honest and ethical reporting of findings. o Logical arguments should be evaluated with open-mindedness, objectivity and skepticism. • Science arguments are strengthened by multiple lines of evidence supporting a single explanation. • The various scientific disciplines have practices, methods, and modes of thinking that are used in the process of developing new science knowledge and critiquing existing knowledge.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• Science depends on curiosity, imagination, creativity and persistence. • Individuals from different social, cultural and ethnic backgrounds work as scientists and engineers. • Science and engineering are influenced by technological advances and society; technological advances and society are influenced by science and engineering. • Science and technology might raise ethical, social and cultural issues for which science, by itself, does not provide answers and solutions.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• Science can advance through critical thinking about existing evidence. • Science includes the process of comparing patterns of evidence with current theory. • Some science knowledge pertains to probabilities or tendencies. • Science should carefully consider and evaluate anomalies (persistent outliers) in data and evidence. • Improvements in technology allow us to gather new scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Physics continued

P.M: MOTION
P.M.1: Motion graphs

- Position vs. time
- Velocity vs. time
- Acceleration vs. time

CONTENT ELABORATION: MOTION

In physical science, the concepts of position, displacement, velocity and acceleration were introduced and straight-line motion involving either uniform velocity or uniform acceleration was investigated and represented in position vs. time graphs, velocity vs. time graphs, motion diagrams and data tables.

In this course, acceleration vs. time graphs are introduced and more complex graphs are considered that have both positive and negative displacement values and involve motion that occurs in stages (e.g., an object accelerates then moves with constant velocity). Symbols representing acceleration are added to motion diagrams and mathematical analysis of motion becomes increasingly more complex. Motion is explored through investigation and experimentation. Motion detectors and computer graphing applications can be used to collect and organize data. Computer simulations and video analysis can be used to analyze motion with greater precision.

P.M.1: Motion graphs
Instantaneous velocity for an accelerating object can be determined by calculating the slope of the tangent line for some specific instant on a position vs. time graph. Instantaneous velocity will be the same as average velocity for conditions of constant velocity, but this is rarely the case for accelerating objects. The position vs. time graph for objects increasing in speed will become steeper as they progress and the position vs. time graph for objects decreasing in speed will become less steep.

On a velocity vs. time graph, objects increasing in speed will slope away from the x-axis and objects decreasing in speed will slope toward the x-axis. The slope of a velocity vs. time graph indicates the acceleration so the graph will be a straight line (not necessarily horizontal) when the acceleration is constant. Acceleration is positive for objects speeding up in a positive direction or objects slowing down in a negative direction. Acceleration is negative for objects slowing down in a positive direction or speeding up in a negative direction. These are not concepts that should be memorized, but can be developed from analyzing the definition of acceleration and the conditions under which acceleration would have these signs.

The word "deceleration" should not be used since it provides confusion between slowing down and negative acceleration. The area under the curve for a velocity vs. time graph gives the change in position (displacement) but the absolute position cannot be determined from a velocity vs. time graph. Objects moving with uniform acceleration will have a horizontal line on an acceleration vs. time graph. This line will be at the x-axis for objects that are either standing still or moving with constant velocity. The area under the curve of an acceleration vs. time graph gives the change in velocity for the object, but the displacement, position and the absolute velocity cannot be determined from an acceleration vs. time graph. The details about motion graphs should not be taught as rules to memorize, but rather as generalizations that can be developed from interpreting the graphs.

P.M.2: Problem solving
Many problems can be solved from interpreting graphs and charts as detailed in the motion graphs section. In addition, when acceleration is constant, average velocity can be calculated by taking the average of the initial and final instantaneous velocities ($v_{avg} = (v_f - v_i)/2$). This relationship does not hold true when the acceleration changes. The equation can be used in conjunction with other kinematic equations to solve increasingly complex problems, including those involving free fall with negligible air resistance in which objects fall with uniform acceleration. Near the surface of Earth, in the absence of other forces, the acceleration of freely falling objects is 9.81 m/s^2. Assessments of motion problems, including projectile motion, will not include problems that require the quadratic equation to solve.

P.M.3: Projectile motion
When an object has both horizontal and vertical components of motion, as in a projectile, the components act independently of each other. For a projectile in the absence of air resistance, this means that horizontally, the projectile will continue to travel at constant speed just like it would if there were no vertical motion. Likewise, vertically the object will accelerate just as it would without any horizontal motion. Problem solving will be limited to solving for the range, time, initial height, initial velocity or final velocity of horizontally launched projectiles with negligible air resistance. While it is not inappropriate to explore more complex projectile problems, it must not be done at the expense of other parts of the curriculum.

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
	P.M.1: Motion graphs		
	Construct a method to measure the changing velocity of an object falling from a height of at least 5.0 m and that of an object rising into the air for at least 5.0 m.	Given a position vs. time graph or velocity vs. time graph write a driving scenario that fits the graph given. Given a position vs. time graph, velocity vs. time graph or acceleration vs. time graph sketch the other two corresponding graphs.	Determine the collision point for two constant velocity buggies traveling at different velocities and moving towards each other. Create a position vs. time graph from given data and determine the velocity of an object at two different times. Use that data to determine the average acceleration of the object during that interval of time. Given a velocity vs. time graph showing quadrants I and IV, label portions of the graph where acceleration is positive or negative and describe the motion of the object as increasing or decreasing by relating slope of the line to sign of acceleration. This clarifies the misconception of negative acceleration always indicating that an object is slowing down. Given unlabeled graphs with a variety of shapes (e.g., constant positive slope, increasing positive slope, zero slope), give an example for an object that would produce a graph for each of the relevant motion graphs.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.M.2: Problem solving			
	Use a constant velocity buggy and an accelerating cart to investigate the simultaneous motion of two objects. Collect data individually on the motion of each object as it travels down a ramp. Use the data to make a prediction for when the accelerating object will overtake the constant velocity object if released at a specified later time. Test your prediction. Compare predictions with actual results and provide possible explanations for any discrepancies. Investigate the motion of a freely falling body using either a ticker timer or a motion detector. Use mathematical analysis to determine a value for "g." Compare the experimental value to known values of "g." Suggest sources of error and possible improvements to the experiment.	Using kinematic equations, solve simultaneous equations to determine when an accelerating object will overtake an object moving at constant velocity (e.g., the police officer and speeder problem). Consider constraints such as the maximum velocity the accelerating object can travel and reaction times if applicable. Experimentally determine reaction time or velocity of a jump using kinematic equations and data collected in class (e.g., distance a ruler drops before catching, height of jump, time in air).	Use the kinematic equations to solve for unknown quantities regarding an accelerated body in one dimension. Solve for information in one part of a problem and use the results to solve for information in subsequent parts.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.M.3: Projectile motion			
	Design an experiment to collect data that will determine the launch velocity of a projectile launcher. Use the data to predict the range of the projectile at a given angle and attempt to hit a target with a projectile. Then, describe any assumptions made (e.g., neglecting air resistance, accounting for any uncertainty in the measurements).	Predict the range of a ball rolling off a table by measuring the speed of the ball on the table and determining the time the ball will take to fall by measuring the height of the table. Using a target placed on the floor, determine how accurate predictions were. Then, identify sources of uncertainty in measurements and explain the effect these had on experimental results.	Solve problems involving horizontal projectiles and recognize that the horizontal velocity does not affect the time that a horizontal projectile will spend in the air.
Investigation of motion			
Given a ramp and a low-friction rolling cart, investigate accelerated motion. Design a procedure to collect relevant position vs. time data for the rolling cart and create a graph of the data. Use the position vs. time graph to determine the acceleration of the rolling cart, either by taking the slope of the graph at various times to determine the velocity and then graphing the velocity values to get a velocity vs. time graph and taking the slope of the graph or by linearizing the data and making use of appropriate kinematics equations.	Given a toy car that travels at a constant velocity, collect data to determine the velocity of the car from a position vs. time graph. The speeds of the cars can be varied by replacing a battery with an aluminum cylinder of the same length or a wooden dowel wrapped in aluminum foil.	Predict where a rolling cart and a constant velocity car will be at the same position on a ramp. Make this prediction by graphing the data for both cars on the same coordinate grid and using algebraic analysis of the data obtained from the previous parts (e.g., the acceleration of the rolling cart and the velocity of the car). Test the prediction and analyze any sources of uncertainty.	

Physics continued

P.F: FORCES, MOMENTUM AND MOTION
P.F.1: Newton's laws applied to complex problems
P.F.2: Gravitational force and fields
P.F.3: Elastic forces
P.F.4: Friction force (static and kinetic)
P.F.5: Air resistance and drag
P.F.6: Forces in two dimensions

- Adding vector forces
- Motion down inclines
- Centripetal forces and circular motion

P.F.7: Momentum, impulse and conservation of momentum

CONTENT ELABORATION: FORCES, MOMENTUM AND MOTION

In earlier grades, Newton's laws of motion were introduced, gravitational forces and fields were described conceptually, the gravitational force (weight) acting on objects near Earth's surface was calculated, and friction forces and drag were addressed conceptually and quantified from force diagrams. The forces required for circular motion were introduced conceptually. In this course, Newton's laws of motion are applied to mathematically describe and predict the effects of forces on more complex systems of objects and to analyze falling objects that experience significant air resistance.

Gravitational forces are studied as a universal phenomenon and gravitational field strength is quantified. Elastic forces and a more detailed look at friction are included. At the atomic level, contact forces are actually due to the forces between the charged particles of the objects that appear to be touching. These electric forces are responsible for friction forces, normal forces and other contact forces. Air resistance and drag are explained using the particle nature of matter. Projectile motion is introduced and circular motion is quantified. The vector properties of momentum and impulse are introduced and used to analyze elastic and inelastic collisions between objects. Analysis of experimental data collected in laboratory investigations is used to study forces and momentum. This can include the use of force probes and computer software to collect and analyze data.

P.F.1: Newton's laws applied to complex problems
Newton's laws of motion, especially the third law, can be used to solve complex problems that involve systems of many objects that move together as one (e.g., an Atwood machine). The equation $a = F_{net}/m$ that was introduced in physical science can be used to solve more complex problems involving systems of objects and situations involving forces that must themselves be quantified (e.g., gravitational forces, elastic forces, friction forces).

P.F.2: Gravitational force and fields
Gravitational interactions are very weak compared to other interactions and are difficult to observe unless one of the objects is extremely massive (e.g., the sun, planets, moons). The force law for gravitational interaction states that the strength of the gravitational force is proportional to the product of the two masses and inversely proportional to the square of the distance between the centers of the masses, $F_g = (G \cdot m_1 \cdot m_2)/r^2$. The proportionality constant, G, is called the universal gravitational constant and has a value of $6.674 \cdot 10^{-11}$ $m^3/(kg \cdot s^2)$. Problem solving may involve calculating the net force for an object between two massive objects (e.g., Earth-moon system, planet-sun system) or calculating the position of such an object given the net force.

The strength of an object's (i.e., the source's) gravitational field at a certain location, g, is given by the gravitational force per unit of mass experienced by another object placed at that location, $g = F_g/m$. Comparing this equation to Newton's second law can be used to explain why all objects on Earth's surface accelerate at the same rate in the absence of air resistance. While the gravitational force from another object can be used to determine the field strength at a particular location, the field of the object is always there, even if the object is not interacting with anything else. The field direction is toward the center of the source. Given the gravitational field strength at a certain location, the gravitational force between the source of that field and any object at that location can be calculated. Greater gravitational field strengths result in larger gravitational forces on masses placed in the field. Gravitational fields can be represented by field diagrams obtained by plotting field arrows at a series of locations. Field line diagrams are excluded from this course. Distinctions between gravitational and inertial masses are excluded.

A scale indicates weight by measuring the normal force between the object and the surface supporting it. The reading on the scale accurately measures the weight if the system is not accelerating. However, if the scale is used in an accelerating system, as in an elevator, the reading on the scale does not equal the actual weight. The scale reading can be referred to as the "apparent weight." This apparent weight in accelerating elevators can be explained and calculated using force diagrams and Newton's laws.

P.F.3: Elastic forces
Elastic materials stretch or compress in proportion to the load they support. The mathematical model for the force that a linearly elastic object exerts on another object is $F_{elastic} = k\Delta x$, where Δx is the displacement of the object from its relaxed position. The direction of the elastic force is always toward the relaxed position of the elastic object. The constant of proportionality, k, is the same for compression and extension and depends on the "stiffness" of the elastic object.

P.F.4: Friction force (static and kinetic)
The amount of kinetic friction between two objects depends on the electric forces between the atoms of the two surfaces sliding past each other. It also depends upon the magnitude of the normal force that pushes the two surfaces together. This can be represented mathematically as $F_k = \mu_k F_N$, where μ_k is the coefficient of kinetic friction that depends upon the materials of which the two surfaces are made.

Sometimes friction forces can prevent objects from sliding past each other, even when an external force is applied parallel to the two surfaces that are in contact. This is called static friction, which is mathematically represented by $F_s \le \mu_s F_N$. The maximum amount of static friction possible depends on the types of materials that make up the two surfaces and the magnitude of the normal force pushing the objects together, $F_{smax} = \mu_s F_N$. As long as the external net force is less than or equal to the maximum force of static friction, the objects will not move relative to one another. In this case, the actual static friction force acting on the object will be equal to the net external force acting on the object, but in the opposite direction. If the external net force exceeds the maximum static friction force for the object, the objects will move relative to each other and the friction between them will no longer be static friction, but will be kinetic friction.

P.F.5: Air resistance and drag
Liquids have more drag than gases. When an object pushes on the particles in a fluid, the fluid particles can push back on the object according to Newton's third law and cause a change in motion of the object. This is how helicopters experience lift and how swimmers propel themselves forward. Forces from fluids are quantified using Newton's second law and force diagrams. Factors that affect air resistance and drag and the determination of terminal velocity may be included.

P.F.6: Forces in two dimensions

- Adding vector forces
- Motion down inclines
- Centripetal forces and circular motion

Net forces will be calculated for force vectors with directions between 0° and 360° or a certain angle from a reference (e.g., 37° above the horizontal). Vector addition can be done with trigonometry or by drawing scaled diagrams. Problems can be solved for objects sliding down inclines. The net force, final velocity, time, displacement and acceleration can be calculated. Inclines will either be frictionless or the force of friction will already be quantified. Calculations of friction forces down inclines from the coefficients of friction and the normal force will not be addressed in this course.

An object moves at constant speed in a circular path when there is a constant net force that is always directed at right angles to the direction of motion toward the center of the circle. In this case, the net force causes an acceleration that shows up as a change in direction. If the force is removed, the object will continue in a straight-line path. The nearly circular orbits of planets and satellites result from the force of gravity. Centripetal acceleration is directed toward the center of the circle and can be calculated by the equation $a_c = v^2/r$, where v is the speed of the object and r is the radius of the circle. This expression for acceleration can be substituted into Newton's second law to calculate the centripetal force. Since the centripetal force is a net force, it can be equated to friction (unbanked curves), gravity, elastic force, etc., to perform more complex calculations.

P.F.7: Momentum, impulse and conservation of momentum

Momentum, p, is a vector quantity that is directly proportional to the mass, m, and the velocity, v, of the object. Momentum is in the same direction the object is moving and can be mathematically represented by the equation $p = mv$. The conservation of linear momentum states that the total (net) momentum before an interaction in a closed system is equal to the total momentum after the interaction. In a closed system, linear momentum is always conserved for elastic, inelastic and totally inelastic collisions. While total energy is conserved for any collision, in an elastic collision, the kinetic energy also is conserved. Given the initial motions of two objects, qualitative predictions about the change in motion of the objects due to a collision can be made. Problems can be solved for the initial or final velocities of objects involved in inelastic and totally inelastic collisions. Momentum may be dealt with in two dimensions conceptually, but at this level calculations should be limited to only one dimension. Coefficients of restitution are beyond the scope of this course.

Impulse, Δp, is the total momentum transfer into or out of a system. Any momentum transfer is the result of interactions with objects outside the system and is directly proportional to both the average net external force acting on the system, F_{avg}, and the time interval of the interaction, t. It can mathematically be represented by $\Delta p = p_f - p_i = F_{avg}\,\Delta t$. This equation can be used to justify why momentum changes due to the external force of friction can be ignored when the time of interaction is extremely short. Average force, initial or final velocity, mass or time interval can be calculated in multi-step word problems. For objects that experience a given impulse (e.g., a truck coming to a stop), a variety of force/time combinations are possible. The time could be small, which would require a large force (e.g., the truck crashing into a brick wall to a sudden stop). Conversely, the time could be extended which would result in a much smaller force (e.g., the truck applying the brakes for a long period of time).

EXPECTATIONS FOR LEARNING

The content in the standards needs to be taught in ways that incorporate the nature of science and engage students in scientific thought processes. Where possible, real-world data and problem- and project-based experiences should be utilized. *Ohio's Cognitive Demands* relate to current understanding and research about the ways people learn and are important aspects to the overall understanding of science concepts. Care should be taken to provide students opportunities to engage in all four types of thinking. Additionally, lessons need to be designed so that they incorporate the concepts described in the *Nature of Science*.

VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.F.1: Newton's laws applied to complex problems			
	Plan and conduct an investigation using an Atwood machine. Vary one of the masses to determine the effect it has on the acceleration of the system. This can be accomplished by measuring the time for one mass to fall a known distance and using kinematics equations to solve for the acceleration or by measuring the acceleration using smart pulleys and computer data logging if it is available. Then, state the relationship mathematically and verify the numerical values from data.	Draw free body diagrams for objects and use them to apply Newton's Second Law to solve for the acceleration of a mass. Design a demonstration for one of Newton's Laws and present the demonstration to the class. The demonstration should provide clear evidence for the law and sufficient data should be collected to support claims. Have classmates critique the demonstration and provide suggested improvements. Calculate the drag force (air resistance) on coffee filters by dropping different quantities and analyzing the experimental data. Determine the factors that affect terminal velocity.	Solve for the acceleration of a mass that is acted upon by multiple forces acting in one dimension. Solve problems for both horizontal and vertical acceleration. **Note:** *Once friction and elastic forces are introduced, these concepts should be integrated into students learning experiences*.
P.F.2: Gravitational forces and fields			
	Use the Phet Gravity Force Lab to investigate the relationship between masses of objects, distance between them and gravitational force. Verify the force law for gravitational interaction using values from the simulation.		Solve problems using the equation for universal gravitation (e.g., determine the net force on a mass at a point between Earth and another stellar object, determine why the gravitational force between two people is negligible, determine the value for g from the equation and Newton's Second Law).

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.F.3: Elastic forces			
Construct a bungee jump apparatus to safely drop a fragile object (e.g., flour bag) to within a specified distance of the ground from an appropriate height, using calculations alone to determine length and strength of bungee cord required. After construction, test bungees to compare elastic force and gravitational force on the object and use data to critique and modify designs.	Plan and conduct a scientific investigation to determine the relationship between the force exerted on a spring and the amount it stretches. Represent the data graphically. Analyze the data to determine patterns and trends and model the relationship with a mathematical equation. Describe the relationship in words and support the conclusion with experimental evidence.	Draw a free body diagram that shows the forces acting on a mass that is hanging from a spring. Draw the forces acting on a mass that is attached to an ideal spring that is not stretched in the vertical direction and is then released. Diagrams can be drawn at the initial position, the equilibrium position, the maximum stretched distance, and at the points halfway between equilibrium and the ends of the motion. The forces and the motion of the spring should only be discussed qualitatively at this point.	Calculate the force on a mass that is hanging in equilibrium by relating the force of gravity and the force applied by the spring.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.F.4: Friction forces (static and kinetic)			
	Plan and conduct an investigation to determine the coefficient of kinetic friction between two surfaces. Collect sufficient relevant data and analyze the data graphically to determine the value for the coefficient of kinetic friction. Then, compare the value to either the accepted value of kinetic friction when possible or to the results of other students and discuss any differences and sources of uncertainty in measurements. Conduct an investigation to measure the coefficient of static friction between two surfaces by changing variables such as mass, incline and types of surfaces. Design an investigation to support or refute the claim that speed or surface area affects the value for the force of friction between two surfaces. Present experimental designs and results to the class and allow others to question the design and the validity of the results.		Solve problems involving calculations of the force of kinetic friction between two surfaces. Problems should include objects moving at constant velocity, objects that are accelerating due to an external force other than friction, and situations where friction is the only force acting on an object to slow it to a stop. Kinematic equations may be included to allow students to determine stopping distance or time for an object to slide to a stop. Draw free body diagrams in conjunction with these problems.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.F.5: Air resistance and drag			
			Determine the magnitude of the air resistance or drag acting on an object when provided with all other forces and the acceleration. Represent the force of air resistance in free body diagrams.
P.F.6: Forces in two dimensions			
	Investigate the relationship between acceleration and the angle of the incline for an object accelerating down an incline in the absence of friction using a low friction cart. Investigate the relationship between acceleration and mass of the object. This can be done at a fixed angle with or without the presence of frictional force. Discuss why no relationships exist. Collect data to investigate the relationship between the speed of an object moving in a circular path and the force needed to keep the object moving in that path. Plot a graph of force vs. velocity and analyze the relationship.	Draw a free-body diagram for an object that is accelerating along a horizontal surface under the influence of a force that acts at a known angle to the horizontal. Use the free-body diagram to solve for the acceleration of the object. The object may be acted on by friction and subject to more than one external force. Use a free-body diagram and trigonometry or scale diagrams to determine the acceleration of an object accelerating down a frictionless incline. Make use of kinematic equations to solve for the time to slide down the incline, the final velocity, or the length of the incline when the appropriate information is provided.	Solve for the components of a force that is at an angle to a known reference. Add force components that act at right angles. Both can be done using either trigonometry or by drawing scale diagrams. Solve problems involving an object accelerating down an incline with a known force of friction. Use kinematic equations to solve for the time to slide down the incline, the final velocity, or the length of the incline when the appropriate information is provided. Solve problems involving objects moving in circular motion (e.g., satellites orbiting planets, cars driving around horizontal curves, planes flying in horizontal and vertical circles). Identify what force is providing the necessary centripetal force for each situation.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.F.7: Momentum, impulse and conservation of momentum			
Research a stretch of road where there are many accidents. Evaluate potential causes related to laws of motion and propose a design change to the road to reduce the number of accidents. Design a system to safely stop a vehicle. Construct a working model that allows a raw egg mounted on the front of a vehicle to remain whole when the vehicle stops before impacting a wall. Test components and systems to collect and analyze data. Use data to refine designs and retest. Use a design portfolio to keep track of trials and revisions to the design throughout the process. Discuss advantages and disadvantages of various braking systems.		Research the effect of snow, rain and ice on the coefficients of friction between tires and the road and use this knowledge to create a presentation for other students on the importance of driving appropriately for the road conditions. Present data using posters to display in the school to raise awareness among the students about the effects that changes in weather conditions can have on driving.	

Physics continued

P.E: ENERGY
P.E.1: Gravitational potential energy
P.E.2: Energy in springs
P.E.3: Work and power
P.E.4: Conservation of energy
P.E.5: Nuclear energy

CONTENT ELABORATION: ENERGY

In Physical Science, the role of strong nuclear forces in radioactive decay, half-lives, fission and fusion, and mathematical problem solving involving kinetic energy, gravitational potential energy, energy conservation and work (when the force and displacement were in the same direction) were introduced. In this course, the concept of gravitational potential energy is understood from the perspective of a field, elastic potential energy is introduced and quantified, nuclear processes are explored further, and the concept of mass-energy equivalence is introduced. The concept of work is expanded, power is introduced and the principle of conservation of energy is applied to increasingly complex situations. Energy is explored by analyzing data gathered in scientific investigations. Computers and probes can be used to collect and analyze data.

P.E.1: Gravitational potential energy
When two attracting masses interact, the kinetic energies of both objects change but neither is acting as the energy source or the receiver. Instead, the energy is transferred into or out of the gravitational field around the system as gravitational potential energy. A single mass does not have gravitational potential energy. Only the system of attracting masses can have gravitational potential energy. When two masses are moved farther apart, energy is transferred into the field as gravitational potential energy. When two masses are moved closer together, gravitational potential energy is transferred out of the field.

P.E.2: Energy in springs
The approximation for the change in the potential elastic energy of an elastic object (e.g., a spring) is $\Delta E_{elastic} = \frac{1}{2} k \Delta x^2$ where Δx is the distance the elastic object is stretched or compressed from its relaxed length.

P.E.3: Work and power
Work can be calculated for situations in which the force and the displacement are at angles to one another using the equation $W = F\Delta x(\cos\theta)$ where W is the work, F is the force, Δx is the displacement, and θ is the angle between the force and the displacement. This means when the force and the displacement are at right angles, no work is done and no energy is transferred between the objects. Such is the case for circular motion.

The rate of energy change or transfer is called power (P) and can be mathematically represented by $P = \Delta E/\Delta t$ or $P = W/\Delta t$. Power is a scalar property. The unit of power is the watt (W), which is equivalent to one joule of energy transferred in one second (J/s).

P.E.4: Conservation of energy
The total initial energy of the system and the energy entering the system are equal to the total final energy of the system and the energy leaving the system. Although the various forms of energy appear very different, each can be measured in a way that makes it possible to keep track of how much of one form is converted into another. Situations involving energy transformations can be represented with verbal or written descriptions, energy diagrams and mathematical equations. Translations can be made between these representations.

The conservation of energy principle applies to any defined system and time interval within a situation or event in which there are no nuclear changes that involve mass-energy equivalency. The system and time interval may be defined to focus on one particular aspect of the event. The defined system and time interval may then be changed to obtain information about different aspects of the same event.

P.E.5: Nuclear energy
Alpha, beta, gamma and positron emission each have different properties and result in different changes to the nucleus. The identity of new elements can be predicted for radioisotopes that undergo alpha or beta decay. Nuclear reactions, such as fission and fusion, are accompanied by large energy changes that are much greater than those that accompany chemical reactions. Nuclear fission reactions are used as a controlled source of energy in nuclear power plants. There are advantages and disadvantages of generating electricity from fission and fusion. During nuclear interactions, the transfer of energy out of a system is directly proportional to the change in mass of the system as expressed by $E = mc^2$, which is known as the equation for mass-energy equivalence. A very small loss in mass is accompanied by a release of a large amount of energy. In nuclear processes such as nuclear decay, fission and fusion, the mass of the product is less than the mass of the original nuclei. The missing mass appears as energy. This energy can be calculated for fission and fusion when given the masses of the particle(s) formed and the masses of the particle(s) that interacted to produce them.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.E.1: Gravitational potential energy			
Design a gravity-fed water system, connecting concepts of rise/fall to gravitational potential energy. Evaluate the system's real-world function compared to predicted performance, considering factors affecting performance (e.g., effects of pipe diameter). Use data to critique designs and propose changes for reconstruction.			Solve problems involving gravitational potential energy. Use problems that involve objects near the surface of Earth as well as objects that have a large distance between their centers of mass, such as a satellite orbiting Earth.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.E.2: Energy in springs			
Attempt to measure/calculate k values for a variety of bungee shock cords. Then construct a bungee jump apparatus to safely drop a fragile object (ex. flour bag, egg) to within a specified distance of the ground from an appropriate height, using calculations alone to determine length and strength of bungee cord required. After construction, compare elastic force and gravitational force on the object and use data to critique designs and propose changes for reconstruction.		Referring to a force vs. distance graph for a spring, interpret what the slope of the line represents (the spring constant, k, measured in N/m) and what the area under the line represents (the energy stored in the spring in joules).	Calculate the amount of energy stored in a spring that is stretched or compressed a certain distance. Referring to a force vs. distance graph, recognize that the force of a spring is changing as a spring oscillates.
P.E.3: Work and power			
	Plan an investigation into the rate at which work can be done by a student. Choose a task that does work on a system (e.g., running up a flight of stairs, raising a mass a certain distance) and measure the amount of work done by the student. Calculate each student's average power. Compare the values for the power and discuss possible reasons for differences obtained by similar tasks performed by different students.	Compare the use of a horizontal force, the use of a force angled above the horizontal, and a force at the same angle below the horizontal to determine which situation transfers the greatest total amount of energy to the system, both with and without friction present.	Solve problems determining the work done on an object by a force that acts at an angle to the displacement of the object. Use free body diagrams to solve for unknown forces. Solve problems determining the rate at which energy is added or removed from an object or a system of objects. Calculations should be limited to calculations involving the average power or the instantaneous power delivered to an object moving at a constant velocity.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.E.4: Conservation of energy			
Investigate a system that transforms mechanical energy to determine the average force of friction on the system and refine the system to improve its efficiency. Compare the efficiency of the system before and after student refinements.	Plan and conduct an investigation into an existing system that transforms mechanical energy from one form into another. Determine an unknown quantity or value associated with the system (e.g., spring constant of a rubber band, mass of an unknown object), and make measurements to calculate the unknown quantity. The value for the unknown quantity can be measured directly and compared to the experimentally determined value. Uncertainties in measurement and assumptions made by the students should be included. Design a method to predict where an object sliding down a ramp onto a flat surface will stop. Determine what data and calculations are needed to make accurate predictions. Collect the necessary data and make predictions for a variety of objects. Compare predictions to actual stopping points. Identify assumptions and other factors that account for discrepancies.	Solve problems using the principle of energy conservation to determine information about a system, such as the final velocity of a mass or the height an object will obtain. These problems should require the use of free body diagrams and the application of Newton's Laws to solve for unknown forces and may include multiple forms of energy transformations (e.g., initial elastic potential energy transformed into kinetic and gravitational potential energy). External forces, such as friction, should be included in problems.	Draw diagrams or graphs to represent energy flow into or out of a system.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		P.E.5: Nuclear energy	
		Predict the products of a given decay process or identify the decay process given the reactants and products.	From given reactions, calculate the masses of the reactants and the products to find the mass defect and hence the energy released in fission and fusion reactions.
		Energy transformation system	
Design a system to complete a task, such as raising a mass a certain distance or compressing a spring or a spring-loaded lever. Use the smallest amount of initial energy to complete the task. Test and refine the design to minimize energy transferred out of the system.	Investigate each energy transformation in the system and take measurements to provide data to calculate the amount of energy present. Calculate energy before and after each transformation. Estimates for energy lost at each transformation should be recorded throughout the design process.	For each of the transformations in the system describe the type of energy and show how values for the energy present, lost and remaining at each step in the process were determined.	Identify the energy present before and after each transformation in the system and accurately calculate the amount of energy present at each step in the process.
		Nuclear power plant	
Research consequences of using nuclear energy as a source of electrical energy production in a particular area. Choose to support or oppose the construction of a nuclear power plant in that area. Identify design changes that could be incorporated to a nuclear power plant that would make it more suitable for use in the area.		Research concepts such as nuclear waste storage, decay series, energy production from fossil fuels, and other related concepts to provide scientific evidence for the recommendation. Present and explain the scientific evidence.	Relate the scientific principles associated with electrical energy production through nuclear fission to the argument for or against construction of a nuclear power plant.

Physics continued

P.W: WAVES
P.W.1: Wave properties
- Conservation of energy
- Reflection
- Refraction
- Interference
- Diffraction

P.W.2: Light phenomena
- Ray diagrams (propagation of light)
- Law of reflection (equal angles)
- Snell's law
- Diffraction patterns
- Wave—particle duality of light
- Visible spectrum of color

CONTENT ELABORATION: WAVES

In earlier grades, the electromagnetic spectrum and basic properties (wavelength, frequency, amplitude) and behaviors of waves (absorption, reflection, transmission, refraction, interference, diffraction) were introduced. In this course, conservation of energy is applied to waves and the measurable properties of waves (wavelength, frequency, amplitude) are used to mathematically describe the behavior of waves (index of refraction, law of reflection, single- and double-slit diffraction). The wavelet model of wave propagation and interactions is not addressed in this course. Waves are explored experimentally in the laboratory. This may include, but is not limited to, water waves, waves in springs, the interaction of light with mirrors, lenses, barriers with one or two slits and diffraction gratings.

P.W.1: Wave properties
When a wave reaches a barrier or a new medium, a portion of its energy is reflected at the boundary and a portion of the energy passes into the new medium. Some of the energy that passes to the new medium may be absorbed by the medium and transformed to other forms of energy, usually thermal energy, and some continues as a wave in the new medium. Some of the energy may also be dissipated and no longer be part of the wave since it has been transformed into thermal energy or transferred out of the system due to the interaction of the system with surrounding objects. Usually all of these processes occur simultaneously, but the total amount of energy must remain constant.

When waves bounce off barriers (reflection), the angle at which a wave approaches the barrier (angle of incidence) equals the angle at which the wave reflects off the barrier (angle of reflection). When a wave travels from a two-dimensional (e.g., surface water, seismic waves) or three-dimensional (e.g., sound, electromagnetic waves) medium into another medium in which the wave travels at a different speed, both the speed and the wavelength of the transferred wave change. Depending on the angle between the wave and the boundary, the direction of the wave can also change, resulting in refraction. The amount of bending of waves around barriers or small openings (diffraction) increases with decreasing wavelength. When the wavelength is smaller than the obstacle or opening, no noticeable diffraction occurs. Standing waves and interference patterns between two sources are included in this topic. As waves pass through a single or double slit, diffraction patterns are created with alternating lines of constructive and destructive interference. The diffraction patterns demonstrate predictable changes as the width of the slit(s), spacing between the slits and/or the wavelength of waves passing through the slits changes.

P.W.2: Light phenomena
The path of light waves can be represented with ray diagrams to show reflection and refraction through converging lenses, diverging lenses and plane mirrors. Since light is a wave, the law of reflection applies. Snell's law, $n_1 \sin\theta_1 = n_2 \sin\theta_2$, quantifies refraction in which n is the index of refraction of the medium and θ is the angle the wave enters or leaves the medium as measured from the normal line. The index of refraction of a material can be calculated by the equation $n = c/v$,

where n is the index of refraction of a material, v is the speed of light through the material, and c is the speed of light in a vacuum. Diffraction patterns of light are addressed, including patterns from diffraction gratings.

There are two models of how radiant energy travels through space at the speed of light. One model is that the radiation travels in discrete packets of energy called photons that are continuously emitted from an object in all directions. The energy of these photons is directly proportional to the frequency of the electromagnetic radiation. This particle-like model is called the photon model of light energy transfer. A second model is that radiant energy travels like a wave that spreads out in all directions from a source. This wave-like model is called the electromagnetic wave model of light energy transfer. Strong scientific evidence supports both the particle-like model and wave-like model. Depending on the problem scientists are trying to solve, either the particle-like model or the wave-like model of radiant energy transfer is used. Students are not required to know the details of the evidence that supports either model at this level.

Humans can only perceive a very narrow portion of the electromagnetic spectrum. Radiant energy from the sun or a light bulb filament is a mixture of all the colors of light (visible light spectrum). The different colors correspond to different radiant energies. When white light hits an object, the pigments in the object reflect one or more colors in all directions and absorb the other colors.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.W.1: Wave properties			
Design a parabolic cooker using principles of ray reflection to design the apparatus. After construction and testing, evaluate the success of the design and examine where performance departs from plan.	Plan and conduct an investigation of wave diffraction. Use single or double slit diffraction to experimentally investigate light waves.	Solve problems related to constructive and destructive interference between two waves. Graphically represent the locations where constructive and destructive interference are occurring based on the path of each wave. Calculate the distances mathematically.	Solve problems involving standing waves on strings and in open and closed pipes. Explain the conditions required for standing waves to occur. Calculate the frequency of a standing wave of a given harmonic.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
		P.W.2: Light phenomena	
	Investigate the image formed by a lens. Experimentally determine the focal length of a lens. Investigate the images formed by the lens using a light source placed different distances from the lens (e.g., inside the focal length, outside the focal length, twice the focal length). Experimentally determine the wavelength of a laser using diffraction through a single slit, a double slit, or a diffraction grating.	Draw ray diagrams for light reflecting off plane, concave and convex mirrors to determine the location of the image formed. Describe the properties of the image that is formed using diagrams and calculations. Draw ray diagrams for light refracting through a boundary of two translucent media. Use the diagrams and calculations to describe the properties of the image. Compare images for converging and diverging lenses.	Solve problems to determine the location and properties of an image formed by various mirrors and lenses. Compare the wave model of light to the particle model. Solve refraction problems using Snell's Law to find the index of refraction for a medium.
		Laser maze	
Design a laser maze. Present mazes and challenge other students to solve them.	Use mirrors to direct a beam of light or a laser around obstacles. Use calculations to determine placement of mirrors to hit a target. Diagram the placement of mirrors to be used and test their placement. Refine and update the path diagram as needed.		Accurately apply the law of reflection to correctly predict the path of light reflecting from a mirror.
		Index of refraction	
	Plan and conduct an investigation to determine the index of refraction of a substance. Determine a procedure to collect sufficient and relevant data. Use the data to calculate the index of refraction. Check the calculated value against the theoretical index of refraction (if known).		Select relevant data to collect in order to determine the index of refraction of a substance.

Physics continued

P.EM: ELECTRICITY AND MAGNETISM
P.EM.1: Charging objects (friction, contact and induction)
P.EM.2: Coulomb's law
P.EM.3: Electric fields and electric potential energy
P.EM.4: DC circuits

- Ohm's law
- Series circuits
- Parallel circuits
- Mixed circuits
- Applying conservation of charge and energy (junction and loop rules)

P.EM.5: Magnetic fields
P.EM.6: Electromagnetic interactions

CONTENT ELABORATION: ELECTRICITY AND MAGNETISM

In earlier grades, electric and magnetic potential energy were treated conceptually. The relative number of subatomic particles present in charged and neutral objects, attraction and repulsion between electrical charges and attraction and repulsion between magnetic poles were explored. The concept of fields to conceptually explain forces at a distance was introduced and the concepts of current, potential difference (voltage) and resistance were used to explain circuits. Additionally, connections between electricity and magnetism were made as observed in electromagnets, motors and generators. In this course, the details of electrical and magnetic forces and energy are further explored and can be used as additional examples of energy and forces affecting motion.

P.EM.1: Charging objects (friction, contact and induction)
For all methods of charging neutral objects, one object/system ends up with a surplus of positive charge and the other object/system ends up with the same amount of surplus of negative charge. This supports the law of conservation of charge that states that charges cannot be created or destroyed. Tracing the movement of electrons for each step in different ways of charging objects (rubbing together two neutral materials to charge by friction; charging by contact and by induction) can explain the differences between them. When an electrical conductor is charged, the charge "spreads out" over the surface. When an electrical insulator is charged, the excess or deficit of electrons on the surface is localized to a small area of the insulator.

There can be electrical interactions between charged and neutral objects. Metal conductors have a lattice of fixed positively charged metal ions surrounded by a "sea" of negatively charged electrons that flow freely within the lattice. If the neutral object is a metal conductor, the free electrons in the metal are attracted toward or repelled away from the charged object. As a result, one side of the conductor has an excess of electrons and the opposite side has an electron deficit. This separation of charges on the neutral conductor can result in a net attractive force between the neutral conductor and the charged object. When a charged object is near a neutral insulator, the electron cloud of each insulator atom shifts position slightly so it is no longer centered on the nucleus. The separation of charge is very small, much less than the diameter of the atom. Still, this small separation of charges for billions of neutral insulator particles can result in a net attractive force between the neutral insulator and the charged object.

P.EM.2: Coulomb's law
Two charged objects, which are small compared to the distance between them, can be modeled as point charges. The forces between point charges are proportional to the product of the charges and inversely proportional to the square of the distance between the point charges [$F_e = (k_e\, q_1\, q_2)/r^2$]. Problems may be solved for the electric force, the amount of charge on one of the two objects or the distance between the two objects. Problems may also be solved for three- or four-point charges in a line if the vector sum of the forces is zero. This can be explored experimentally through computer simulations. Electric forces acting within and between atoms are vastly stronger than the gravitational forces acting between the atoms. However, gravitational forces are only attractive and can accumulate in massive objects to produce a large and noticeable effect. Conversely, electric forces are both attractive and repulsive and tend to cancel each other out.

P.EM.3: Electric fields and electric potential energy
The strength of the electrical field of a charged object at a certain location is given by the electric force per unit charge experienced by another charged object placed at that location, $E = F_e/q$. This equation can be used to calculate the electric field strength, the electric force or the electric charge. However, the electric field is always there, even if the object is not interacting with anything else. The direction of the electric field at a certain location is parallel to the direction of the electrical force on a positively charged object at that location. The electric field caused by a collection of charges is equal to the vector sum of the electric fields caused by the individual charges (superposition of charge). This topic can be explored experimentally through computer simulations. Greater electric field strengths result in larger electric forces on electrically charged objects placed in the field. Electric fields can be represented by field diagrams obtained by plotting field arrows at a series of locations. Electric field diagrams for a dipole, two-point charges (both positive, both negative, one positive and one negative) and parallel capacitor plates are included. Field line diagrams are excluded from this course.

The concept of electric potential energy can be understood from the perspective of an electric field. When two attracting or repelling charges interact, the kinetic energies of both objects change but neither is acting as the energy source or the receiver. Instead, the energy is transferred into or out of the electric field around the system as electric potential energy. A single charge does not have electric potential energy. Only the system of attracting or repelling charges can have electric potential energy. When the distance between the attracting or repelling charges changes, there is a change in the electric potential energy of the system. When two opposite charges are moved farther apart or two like charges are moved close together, energy is transferred into the field as electric potential energy. When two opposite charges are moved closer together or two like charges are moved farther apart, electric potential energy is transferred out of the field. When a charge is transferred from one object to another, work is required to separate the positive and negative charges. If there is no change in kinetic energy and no energy is transferred out of the system, the work increases the electric potential energy of the system.

P.EM.4: DC circuits
Once a circuit is switched on, the current and potential difference are experienced almost instantaneously in all parts of the circuit even though the electrons are only moving at speeds of a few centimeters per hour in a current-carrying wire. It is the electric field that travels instantaneously through all parts of the circuit, moving the electrons that are already present in the wire. Since electrical charge is conserved, in a closed system such as a circuit, the current flowing into a branch point junction must equal the total current flowing out of the junction (junction rule).

Resistance is measured in ohms and has different cumulative effects when added to series and parallel circuits. The potential difference, or voltage (ΔV), across an energy source is the potential energy difference (ΔE) supplied by the energy source per unit charge (q) ($\Delta V = \Delta E/q$). The electric potential difference across a resistor is the product of the current and the resistance ($\Delta V = I\,R$). In this course, only ohmic resistors will be studied. When potential difference vs. current is plotted for an ohmic resistor, the graph will be a straight line and the value of the slope will be the resistance. Since energy is conserved for any closed loop, the energy put into the system by the battery must equal the energy that is transformed by the resistors. For circuits with resistors in series, this means that $V_{battery} = \Delta V_1 + \Delta V_2 + \Delta V_3 +\ldots$. The rate of energy transfer (power) across each resistor is equal to the product of the current through and the voltage drop across each resistor ($P = \Delta V\,I$) and $P_{battery} = I\,\Delta V_1 + I\,\Delta V_2 + I\,\Delta V_3 +\ldots = I\Delta V_{battery}$. Equations should be understood conceptually and used to calculate the current or potential difference at different locations of a parallel, series or mixed circuit. However, the names of the laws (e.g., Ohm's law,) are not the focus. Opportunities for measuring and analyzing current, voltage and resistance in parallel, series and mixed circuits should be provided. This can be done with traditional laboratory equipment and through computer simulations.

P.EM.5: Magnetic fields
The direction of the magnetic field at any point in space is the equilibrium direction of the north end of a compass placed at that point. Magnetic fields can be represented by field diagrams obtained by plotting field arrows at a series of locations. Field line diagrams are excluded from this course. Calculations for the magnetic field strength are not required at this grade level, but it is important to note that greater magnetic fields result in larger magnetic forces on magnetic objects or moving charges placed in the field. In this course, the concept of magnetic fields will not be addressed mathematically.

P.EM.6: Electromagnetic interactions
Magnetic forces are very closely related to electric forces. Even though they appear to be distinct from each other, they are thought of as different aspects of a single electromagnetic force. A flow of charged particles (including an electric current) creates a magnetic field around the moving particles or the current carrying wire. Motion in a nearby magnet is evidence of this field. Electric currents in Earth's interior give Earth an extensive magnetic field, which is detected from the orientation of compass needles. The motion of electrically charged particles in atoms produces magnetic fields. Usually these magnetic fields in an atom are randomly oriented and therefore cancel each other out. In magnetic materials, the subatomic magnetic fields are aligned, resulting in a macroscopic magnetic field.

A moving charged particle interacts with a magnetic field. The magnetic force that acts on a moving charged particle in a magnetic field is perpendicular to both the magnetic field and to the direction of motion of the charged particle. The magnitude of the magnetic force depends on the speed of the moving particle, the magnitude of the charge of the particle, the strength of the magnetic field, and the angle between the velocity and the magnetic field. There is no magnetic force on a particle moving parallel to the magnetic field. Calculations of the magnetic force acting on moving particles are not required at this grade level. Moving charged particles in magnetic fields typically follow spiral trajectories since the force is perpendicular to the motion.

A changing magnetic field creates an electric field. If a closed conducting path, such as a wire, is in the vicinity of a changing magnetic field, a current may flow through the wire. A changing magnetic field can be created in a closed loop of wire if the magnet and the wire move relative to one another. This can cause a current to be induced in the wire. The strength of the current depends upon the strength of the magnetic field, the velocity of the relative motion and the number of loops in the wire. Calculations for current induced in a wire or coil of wire is not required at this level. A changing electric field creates a magnetic field and a changing magnetic field creates an electric field. Thus, radiant energy travels in electromagnetic waves produced by changing the motion of charges or by changing magnetic fields. Therefore, electromagnetic radiation is a pattern of changing electric and magnetic fields that travel at the speed of light.

The interplay of electric and magnetic forces is the basis for many modern technologies that convert mechanical energy to electrical energy (generators) or electrical energy to mechanical energy (electric motors) as well as devices that produce or receive electromagnetic waves. Therefore, coils of wire and magnets are found in many electronic devices including speakers, microphones, generators and electric motors. The interactions between electricity and magnetism should be explored in the laboratory setting. Experiments with the inner workings of motors, generators and electromagnets can be conducted. Current technologies using these principles can be explored.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.EM.1: Charging objects			
Investigate alternative solutions to reduce static electricity in clothing tossed in a dryer.		Describe and draw diagrams to explain the process of polarization and the attraction of a charged object and a neutral object in terms of the movement of electrons (e.g., balloon sticking to a wall, balance a meter stick on a golf ball and cause rotation with a charged balloon).	State the differences between conductors and insulators in terms of electron movement through the materials. Describe how electrons move in an electroscope and how the electroscope indicates charge. Represent the methods of charging in a graphic organizer, chart or drawing.
P.EM.2: Coulomb's law			
	Investigate, in the lab or with a computer simulation, electrostatic repulsion and attraction. Devise two procedures to investigate the effects charge and distance have on the magnitude and direction of the force.		Cite the similarities and differences between the equation for gravitational and for electrical force (Coulomb's Law). Solve problems using Coulomb's Law to determine the net force on a charge due to two charges that are not collinear. Explain the relationship between force and distance using a graphical representation.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.EM.3: Electric fields and electric potential energy			
	Use a computer simulation to investigate the effect of charges on the electric field at a point in space and the effect of an external field on a charged particle. Determine the relationships.	Compare Earth's gravitational field with an electric field in terms of when potential energy is increasing and decreasing. Explore the Millikan Oil Drop Experiment. Apply the idea of equilibrium to electrical and gravitational forces.	Solve problems about the force on a charged particle in a constant electric field. Use Newton's Laws, kinematic equations and equations for work and kinetic energy to calculate the acceleration of the particle, the final velocity of the particle and the change in energy of the particle. Describe the relationship between potential energy and electric fields. Draw the field lines for a positive charge, a negative charge, a dipole and two parallel plates of charge.
P.EM.4: DC circuits			
	Use a source of constant voltage to plan and conduct an investigation to determine the relationship between the current and the resistance in a simple DC circuit. Analyze the results mathematically and graphically. Form a claim about the relationship between the current and resistance and support the claim with evidence from the investigation.	Solve problems involving complex circuits with arrangements of resistors in both parallel and series to determine the equivalent resistance of the entire circuit as well as the current, the potential difference, or rate of energy dissipated in individual resistors in the circuit. Compare different types of string lights to explore what type of circuits are involved, how blinker bulbs work and how bulbs that are unlit complete a circuit.	Solve problems involving resistors in series and in parallel to determine the current, potential difference, or rate of energy dissipated in individual resistors in the circuit.
P.EM.5: Magnetic fields			
		Use a small compass to map the magnetic field around a bar magnet, horseshoe magnet and circular magnet. Explain why the shape of the fields is different.	

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
P.EM.6: Electromagnetic interactions			
Design and build a generator that will convert mechanical energy into electrical energy and light three flashlight bulbs. Draw a labeled design plan and write a paper explaining in detail, and in terms of electromagnetic induction, how the details of the design allow the generator to work. Test the generator in an electric circuit. If it cannot supply the electrical energy to light three flashlight bulbs in a series, redesign the generator. Design an electromagnetic motor with a limitation on the amount of materials used in construction. Test the design and redesign the motor based on the findings from the testing process.	Investigate the production of a magnetic field by a current carrying wire. Develop and test a hypothesis about the relationship between an independent variable (e.g., amount of current) and the strength of the generated magnetic field. Using a galvanometer connected to a solenoid and a magnet, design and conduct an investigation to determine when current is induced and what variables affect the strength of the current.	Apply Newton's Laws to predict the shape of the path followed by a charged particle moving in a magnetic field. Draw the path and predict the shape for heavier and lighter particles as well as particles with different charge. Predict the direction of a magnetic field in a current carrying wire. Use a compass and wire demonstration device to check the prediction.	State the factors that affect the force on a moving charged particle in a magnetic field and determine the path taken by the charged particle. Use the right-hand rules to determine the direction of a charged particle in a magnetic field. Discuss the benefits and origins of Earth's magnetic field.
Determining unknown resistance			
	Plan and conduct an investigation to determine the resistance of an unknown resistor. Unanticipated effects on measurements should be accounted for (e.g., internal resistance of the battery or power supply) and assumptions made should be explained (e.g., assuming the resistance of the wires can be ignored or that a voltmeter has an infinite impedance). Experimental design should be checked for safety before conducting the experiment.	Draw a circuit diagram of the experimental design before conducting the experiment, labeling the elements of the circuit.	Calculate the resistance of the resistor, using either an average of the data or by graphing the data and analyzing it.

Human Anatomy and Physiology

INTRODUCTION AND SYLLABUS

COURSE DESCRIPTION

Human Anatomy and Physiology is a high school level course, which satisfies the Ohio Core science graduation requirements of Ohio Revised Code Section 3313.603. This section of Ohio law requires three units of science. Each course should include inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.

Human Anatomy and Physiology comprises a systematic study in which students will examine human anatomy and physical functions. They will analyze descriptive results of abnormal physiology and evaluate clinical consequences. A workable knowledge of medical terminology will be demonstrated.

COURSE CONTENT

The following information may be taught in any order; there is no ODE-recommended sequence.

AP.LO: LEVELS OF ORGANIZATION

AP.LO.1: Hierarchy of Organization
AP.LO.2: Types of Tissues
AP.LO.3: Homeostasis
AP.LO.4: Anatomical Terminology

AP.SM: SUPPORT AND MOTION

AP.SM.1: Integumentary System
AP.SM.2: Skeletal System
AP.SM.3: Muscular System

AP.IC: INTEGRATION AND COORDINATION

AP.IC.1: Nervous System
AP.IC.2: Special Senses

- Sense of Sight
- Senses of Hearing and Balance
- Senses of Taste and Smell

AP.IC.3: Endocrine System

AP.T: TRANSPORT

AP.T.1: Blood
AP.T.2: Cardiovascular System
AP.T.3: Lymphatic and Immune Systems

AP.AE: ABSORPTION AND EXCRETION

AP.AE.1: Digestive System
AP.AE.2: Respiratory System
AP.AE.3: Urinary System

AP.R: REPRODUCTION

AP.R.1: Reproductive System

NATURE OF SCIENCE HIGH SCHOOL

Nature of Science
One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.

Categories	High School
Scientific Inquiry, Practice and Applications All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.	• Identify questions and concepts that guide scientific investigations. • Design and conduct scientific investigations using a variety of methods and tools to collect empirical evidence, observing appropriate safety techniques. • Use technology and mathematics to improve investigations and communications. • Formulate and revise explanations and models using logic and scientific evidence (critical thinking). • Recognize and analyze explanations and models. • Communicate and support scientific arguments.
Science is a Way of Knowing Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.	• Various science disciplines use diverse methods to obtain evidence and do not always use the same set of procedures to obtain and analyze data (i.e., there is no one scientific method). o Make observations and look for patterns. o Determine relevant independent variables affecting observed patterns. o Manipulate an independent variable to affect a dependent variable. o Conduct an experiment with controlled variables based on a question or hypothesis. o Analyze data graphically and mathematically. • Science disciplines share common rules of evidence used to evaluate explanations about natural phenomenon by using empirical standards, logical arguments and peer reviews. o Empirical standards include objectivity, reproducibility, and honest and ethical reporting of findings. o Logical arguments should be evaluated with open-mindedness, objectivity and skepticism. • Science arguments are strengthened by multiple lines of evidence supporting a single explanation. • The various scientific disciplines have practices, methods, and modes of thinking that are used in the process of developing new science knowledge and critiquing existing knowledge.
Science is a Human Endeavor Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.	• Science depends on curiosity, imagination, creativity and persistence. • Individuals from different social, cultural, and ethnic backgrounds work as scientists and engineers. • Science and engineering are influenced by technological advances and society; technological advances and society are influenced by science and engineering. • Science and technology might raise ethical, social and cultural issues for which science, by itself, does not provide answers and solutions.
Scientific Knowledge is Open to Revision in Light of New Evidence Science is not static. Science is constantly changing as we acquire more knowledge.	• Science can advance through critical thinking about existing evidence. • Science includes the process of comparing patterns of evidence with current theory. • Some science knowledge pertains to probabilities or tendencies. • Science should carefully consider and evaluate anomalies (persistent outliers) in data and evidence. • Improvements in technology allow us to gather new scientific evidence.

*Adapted from Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

Human Anatomy and Physiology continued

AP.LO: LEVELS OF ORGANIZATION
AP.LO.1: Hierarchy of organization
AP.LO.2: Types of tissues
AP.LO.3: Homeostasis
AP.LO.4: Anatomical terminology

CONTENT ELABORATION: LEVELS OF ORGANIZATION

AP.LO.1: Hierarchy of organization
Building on knowledge about cell structures and processes from middle school and Biology, this topic focuses on the increasing complexity of cells as they are organized into tissues. Several tissue types make up an organ. Several organs working together make up an organ system. All the organ systems interact and form the human body.

AP.LO.2: Types of tissues
The human body is comprised of four types of tissues: epithelial, connective, muscle and nervous. This topic includes a broad overview of the structure, function and location of each tissue type. Tissues can be studied as an independent unit or as they are encountered within each organ system. Investigations are used to understand and explain types of tissues in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

AP.LO.3: Homeostasis
Homeostasis is a theme that is explored throughout the course. Homeostasis involves positive and negative feedback mechanisms that continuously monitor and adjust the body's internal conditions (e.g., temperature regulation, pH, hormone regulation, blood pressure, hemostasis). At times, there can be a disruption (or disruptions) in the feedback loops, creating an imbalance. This homeostatic imbalance can result in a variety of conditions.

AP.LO.4: Anatomical terminology
Standard anatomical position is to be used as a reference point. Each area of the human body is identified by region. The features and structures of the body, relative to each other, are described by directional terms. The body and its organs can be divided by planes. The organs are located in cavities.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

This section provides guidance for developing classroom tasks that go beyond traditional approaches to instruction. It is a springboard for generating innovative ideas to address the cognitive demands. A variety of activities are presented so that teachers can select those that best meet the needs of their students. This is not an all-inclusive checklist and is not intended to cover every aspect of the standards. **These activities are suggestions and are not mandatory.**

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
AP.LO.1: Hierarchy of organization			
	Research various species of organisms that have been studied in order to understand fundamental physiological processes in humans. Explain the considerations in determining what species is the best to study for a particular process.	Analyze data about various human cell types and hypothesize the relationships between structure and function.	Identify the levels of organization from cellular to organism.
AP.LO.2: Types of tissues			
Simulate tissue engineering using a variety of materials (e.g., gelatin, agar, yeast). Critique the characteristics of each tissue simulation to rate its possible use in tissue grafting.		Use microscopes or virtual images to examine various tissues. Compare a range of epithelial (e.g., squamous, columnar, cuboidal), connective (e.g., cartilage, bone, blood), muscular (e.g., skeletal, cardiac, smooth) and nervous tissues. Interpret how the function of each tissue type relates to its structure.	Create labeled illustrations or models of the four types of human tissues.
AP.LO.3: Homeostasis			
Design or critique a device used to maintain or monitor homeostasis for a human body process (e.g., heart rate, glucose, oxygen level).	Investigate homeostasis by measuring changes in heart rate. Compare resting heart rate to the rate after changing a variable. Present data and hypothesize ways to improve heart rates in stressed individuals (e.g., yoga, deep breathing).	After using a simulation or another data source, discuss how the data are similar to and different from the self-regulation that goes on in an actual human body. Research the chronic changes in the muscular, circulatory, and respiratory systems in response to starting an exercise program. Distinguish which kinds of changes result from which kinds of exercise (e.g., aerobic, anaerobic). Investigate ways that prions, viruses, bacteria, protozoans and multicellular parasites disturb homeostasis. Give examples of diseases caused by each category.	Identify examples of how the body uses homeostasis to maintain balance. Differentiate between positive and negative feedback mechanisms.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
AP.LO.4: Anatomical terminology			
		Demonstrate knowledge of anatomical directional terminology through the dissection of a three-dimensional object, such as a clay model, doll or gummy bear.	Label a diagram of a human body with directional terms, planes and cavities.

Human Anatomy and Physiology continued

AP.SM: SUPPORT AND MOTION
AP.SM.1: Integumentary system
AP.SM.2: Skeletal system
AP.SM.3: Muscular system

CONTENT ELABORATION: SUPPORT AND MOTION

AP.SM.1: Integumentary system
The integumentary system consists of skin and accessory structures. The skin is composed of three layers: the epidermis, the dermis and the hypodermis (subcutaneous layer). The accessory structures can include sweat glands, sebaceous glands, arrector pili muscles, hair follicles and nails. Skin functions include protection, temperature regulation, excretion and sensory perception. These occur through the processes of perspiration, skin production and shedding, vitamin D synthesis and repair. Homeostatic imbalances are explored. These include, but are not limited to, burns, skin cancer, anhidrosis, acne, eczema or scleroderma. Investigations are used to understand and explain the integumentary system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

AP.SM.2: Skeletal system
The skeletal system is composed of bones, cartilage, joints and ligaments. Bones make up most of the skeleton. There are four main cell types that compose bone tissue, each with a specific function: osteogenic cells, osteocytes, osteoblasts and osteoclasts. The microscopic anatomy of compact bone includes osteons. Bones are classified by their shape. The structure of a typical long bone can be explored. Specific bones of the skeleton can be studied by their subdivisions: the axial skeleton and the appendicular skeleton. Cartilage is found in areas of the nose, ears, ribs and joints. Joints can be classified by structure or by function. The general structure of synovial joints may be explored. Ligaments connect bone to bone, stabilizing joints.

The skeletal system provides support for the human body, protects soft organs, allows for movement due to attachment of muscles, stores minerals and fat and forms blood cells. Processes of the skeletal system include hematopoiesis, ossification and bone growth and remodeling. A comparison of male to female, juvenile to adult or human to other vertebrate skeletons may be explored. Homeostatic imbalances are explored. These include, but are not limited to, osteoporosis, malnutrition, fractures, anterior cruciate ligament (ACL) injuries and arthritis. Investigations are used to understand and explain the skeletal system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

AP.SM.3: Muscular system
The muscular system consists of three types of muscle cells: skeletal, smooth and cardiac. The primary function of the muscular system is to contract, thereby, moving the body and internal fluids, maintaining posture, generating heat and stabilizing joints. Muscles are controlled voluntarily and/or involuntarily.

Heart muscle cells are mononucleated, branched and striated. Intercalated disks are characteristic of cardiac muscle and aid in communication between cardiac muscle cells. Smooth muscle cells, found in the hollow organs and blood vessels, are mononucleated, spindle-shaped and nonstriated. Skeletal muscle cells, found attached to bones and skin, are multinucleated, cylindrical and striated. The muscles of the body can be studied by group, which include the muscles of the head, face and neck, the trunk and the upper and lower limbs.

Processes of the muscular system include gross body movements produced by skeletal muscles as they interact with the skeletal system, and muscle contraction. The connection between the nervous system and the skeletal system should be explored through the study of action potentials and the resulting contraction of sarcomeres, as described by the sliding filament theory. Energy processing and muscle responses to stimuli can be studied along with building muscle tissue through exercise. The effects of steroids can also be investigated. Homeostatic imbalances are explored. These include, but are not limited to, muscular dystrophy and atrophy. Investigations are used to understand and explain the muscular system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

EXPECTATIONS FOR LEARNING

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	**Demonstrating science knowledge**	**Interpreting and communicating science concepts**	**Recalling accurate science**
AP.SM.1: Integumentary system			
Skin cells and accessory structures			
		Create labeled illustrations or models of skin cells and accessory structures. Compare the structure and function of the integument of the major classes of vertebrates. Explore the connection between types of cells, accessory structures, and the ability to sense temperature and pressure.	Use microscopes, micrographs, models or illustrations to identify types of skin cells and accessory structures. Describe the process of tissue engineering and tissue donation. Describe what attributes need to be considered in order to be a tissue donor. List sensory structures in the integumentary system.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Skin cancer-UV connection			
Design a sunscreen that does not kill aquatic wildlife (e.g. corals).	Design an investigation to compare various sunscreens and homeopathic methods using UV sensitive paper or UV sensitive yeast strains.	Investigate and present data on the connection between UV/sun exposure and increased incidence of skin cancer. Create a presentation or infographic to inform an audience about the risks of, and dispel common myths about, UV exposure. Propose a plan to lower the incidence of skin cancer. Explore the safety of tanning salons and alternative tanning methods (e.g., spray tanning).	Explain how UV light from sun or tanning salon exposure increases the risks of skin cancer.
Homeostatic imbalances			
		Dispel myths about acne with knowledge about homeostatic imbalances in the integumentary system.	Explain the cause of homeostatic imbalances (e.g., burns, skin cancers, anhidrosis, acne, eczema, scleroderma).
AP.SM.2: Skeletal system			
Structure			
Design and create a model of a prosthetic limb that can a perform a task (e.g., lift or carry an object). Design a bone model with cardstock and tape to meet specific parameters (e.g., strength). Test how well the model meets the parameters.		Compare bone structures in various vertebrates. Associate the structure of bones with their function (e.g., hollow bones in birds, fused radioulna in frogs). Dissection (e.g., chicken legs, pigs, cats) can be used as a point of comparison. Measure femur length and perform associated calculations to find height. Graph results to compare genders and ages.	Create an illustration of a long bone and label all structures. Use models or illustrations to identify and name bones and important bony features of the human skeleton.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Bones			
Design a better cast for fractures, identifying the materials, type of fixation, etc.		Create a model of each type of bone and identify features. Research gender and age data for common fractures. Discuss patterns that emerge. Develop explanations for common injuries for given age/gender classifications. Develop an action plan to help the elderly prevent bone density loss.	Identify, label and describe the types of bones using graphics, images, X-ray images or lab bone specimens. Create an illustration of different stages of bone development and destruction, including fracture repair. List and describe factors that affect bone density.
Anatomical movement			
Design a system to analyze movement/joint stability in specified movements.		Record (e.g., drawings, video) common athletic movements and identify bones and joints involved and anatomical movement represented.	Identify the movement involved in moving specified joints.
AP.SM.3: Muscular system			
Muscle fatigue			
	Design, plan, and conduct an investigation on muscle fatigue using basic exercise equipment (e.g., tennis ball, clothespin, textbook). Collect data and analyze.	Explore muscle fatigue in relationship to handedness, gender, height and other factors.	Provide an example of muscle fatigue and describe the physiology behind it.
Muscles			
Design and construct an artificial hand from common household items where the fingers flex and extend to perform a task.	Choose opposing major muscle groups and design an investigation to compare contraction length and/or force.	Create a presentation describing and differentiating between muscle tissue types. Build a model using household items to demonstrate the steps of the sliding filament theory.	Use microscopes, micrographs, models or illustrations to identify muscle tissue types. Define and describe the types of connective tissue.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Steroids - effects and risks			
		Research and present findings over the uses for steroids, risks of use and alternative treatment options. Create a presentation to inform the public about the risks of anabolic steroid abuse.	Research anabolic steroids, their effects on the body, medical applications and risk factors of their use.
Homeostatic imbalances in muscles			
		Create a product which describes symptoms, treatments and prognosis for varying muscle disorders. Develop a plan to reduce risks and prevent muscle atrophy associated with the disorder.	Identify common muscle disorders and give common symptoms and treatments.

Human Anatomy and Physiology continued

AP.IC: INTEGRATION AND COORDINATION
AP.IC.1: Nervous system
AP.IC.2: Special senses

- Sense of sight
- Senses of hearing and balance
- Senses of taste and smell

AP.IC.3: Endocrine system

CONTENT ELABORATION: INTEGRATION AND COORDINATION

AP.IC.1: Nervous system
The nervous system consists of neurons and supporting cells that combine to form nerves, the spinal cord and the brain. The primary functions of the nervous system are sensation, integration and response. A comparison of the structures and functions of the central and peripheral nervous systems should be explored. The central nervous system is composed of the brain and spinal cord. The peripheral nervous system includes the remaining nervous tissue.

A neuron consists of dendrites, a cell body and an axon. Neurons conduct electrical impulses along their membranes and at synapses. Brain cells can detect and sometimes respond to these impulses. Neuroglial cells help to support neural function.

The brain consists of three major parts: the cerebrum, cerebellum and brainstem. The cerebrum is divided into lobes and hemispheres. Functions of the cerebrum that may be explored include voluntary muscle control, memory, sensory perception, emotions and speech. The cerebellum is primarily responsible for balance and coordination. The brainstem, a part of the autonomic nervous system, includes structural divisions that perform basic life functions such as breathing and heart rate.

The spinal cord is a continuation of the brainstem. The spinal cord is a bundle of nerve tracts that transmits nerve signals between the brain and the body through electrical impulses.

Nerves are bundles of neurons that transmit impulses between the peripheral and central nervous systems. The study of nerves can include sciatic, cranial and spinal nerves. Supporting structures of the central nervous system include the meninges and cerebrospinal fluid which protect the central nervous system.

Processes of the nervous system are action potential propagation, simple nerve pathways (reflex arc) and neurotransmitter function. Homeostatic imbalances are explored. These include, but are not limited to, the effects of drugs, mental illnesses, spinal injuries, concussions, meningitis and multiple sclerosis (MS). Investigations are used to understand and explain the nervous system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

AP.IC.2: Special senses

- Sense of sight
- Senses of hearing and balance
- Senses of taste and smell

The special senses consist of sight, hearing, balance, smell and taste. Each sense involves a network of feedback processes and consists of distinct structures.

Sense of sight

The eye provides visual environmental feedback and includes primary and accessory structures. Light enters through the pupil and is then focused by the lens onto the retina at the visual axis. The optic nerve transmits the electrical impulses to the brain where they are translated. The accessory structures provide lubrication, protection and support to the eye.

Processes include stimulation of the photoreceptors (rods and cones) by light. Homeostatic imbalances are explored. These include, but are not limited to, certain types of blindness, conjunctivitis, glaucoma, astigmatism, hyperopia, myopia and cataracts. Investigations are used to understand and explain the sense of sight in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis (e.g., squid, falcon, hawks) communication skills and real-world applications.

Senses of hearing and balance

The ears respond to a range of sounds and provide a sense of equilibrium. The structures include those of the outer, middle and inner ear. Processes of hearing and balance should be explored including the perception of sound and spatial awareness. Homeostatic imbalances are explored. These include, but are not limited to, certain types of hearing loss, otitis media, lack of balance (e.g., vertigo), tinnitus, auditory processing, motion sickness and Meniere's syndrome. Investigations are used to understand and explain the senses of hearing and balance in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

Senses of taste and smell

The senses of taste and smell occur primarily in the oral and nasal cavities. The structure of taste buds and olfactory cells are the foundation of taste and smell. The location, structure and afferent pathways of taste and smell receptors should be addressed.

Processes include activation of chemoreceptors and transmission of electrical impulses to the brain, where they are integrated. Homeostatic imbalances are explored. These include, but are not limited to, age-related sensitivities, taste preferences, anosmia and olfactory auras. Investigations are used to understand and explain the senses of taste and smell in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

AP.IC.3: Endocrine system

The endocrine system is comprised of glands that secrete hormones resulting in a response in target cells or organs. Glands with their associated hormones may include pituitary, hypothalamus, thyroid, thymus, parathyroid, pineal, pancreas, adrenal, ovaries and testes. The endocrine system results in regulating metabolism, maintaining homeostasis, regulating growth and development, and controlling reproduction through hormonal release.

The processes involved in the endocrine system should include a comparison of negative and positive feedback systems. Negative feedback examples can include regulation of blood glucose levels, calcium levels, blood pressure and temperature. Positive feedback examples can include oxytocin in childbirth and hemostasis.

Homeostatic imbalances are explored. These include, but are not limited to, hyper- and hypo- functions of glands, diabetes (type I and type II), gigantism and dwarfism. Investigations are used to understand and explain the endocrine system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

EXPECTATIONS FOR LEARNING

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
AP.IC.1: Nervous system			
Central nervous system/peripheral nervous system			
Examine the basic design of artificial limbs that integrate with the nervous system to provide the recipient control of the device.	Design and implement an investigation to measure muscular response to stimuli.	Compare the structures and functions of the central nervous system with the structures and functions of the peripheral nervous system. Evaluate scientific claims for and against the use of environmental toxins/neurotoxins (e.g., lead, mercury, radon). Provide peer-reviewed scientific evidence to support your claims.	Identify the main structures and functions of the central nervous system and the peripheral nervous system.
Neurons			
		Construct a 3D model of a neuron that can be used to illustrate anatomy, action potential propagation, simple nerve pathways (reflex arc) and neurotransmitter function. Critique the current treatment(s) available for a neurological disease (e.g., Parkinson's, MS, Huntington's).	Using microscopes, micrographs, models or illustrations, identify the cells of the nervous tissue.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Brain structure/function			
High school athletes are reported to be more susceptible to brain damage than their peers. Use scientific evidence to support or refute this claim. If this claim is accurate, suggest a possible way to reduce Chronic Traumatic Encephalopathy (CTE) injuries in high school athletes. Use correlations of symptoms caused by brain injuries to critique personal protective equipment (e.g., bicycle helmet, hard hats) and suggest modifications to improve their design.	Explore some of the difficulties of investigating brain function and critique the limitations in treating damage and disease in the brain and other parts of the nervous system.	Predict the outcome of tumor growth in different regions of the brain. Relate the development of the brain to decision-making skills. Correlate the relationship between a brain injury occurring in a specific region and the expressed symptoms. Determine the validity of left brain/right brain dominance. Determine if the structure and function of the nervous system are similar to the operating system of a computer. Compare the structure of another vertebrate brain (e.g., sheep) to the human brain.	Use microscopes, micrographs, models or illustrations to identify the main structures of the brain. List the functions of the cerebrum, cerebellum and brainstem. Create labeled illustrations or models of the human brain that include structure and function.
Spinal cord			
	Design an investigation to compare reaction times and reflex times.	Measure reaction and reflex times and explain the differences in your recorded data.	Use microscopes, micrographs, models or illustrations to identify the main structures of the spinal cord.
Nerves			
		Differentiate between spinal and cranial nerves Explain how the density of nerve endings in different body areas and the ability of nerves to adapt to stimuli relate to human physiology.	Use microscopes, micrographs, models or illustrations to identify the main structures of a nerve.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Processes			
Design a prototype of a new medical device for an amputee, including the transfer of electrical impulses to neurons.	Design and implement an investigation to measure the effect of a depressant or stimulant on a model organism's nervous system (e.g., *C. elegans,* Daphnia*)*.	Explain the symptoms of a chosen neurologic disorder based upon the physiology of the disorder. Describe how opioids interfere with chemical communication in the brain. Predict how a change in membrane potential would impact action potential propagation in an axon. Create a model of action potential propagation and/or neurotransmitter function.	Use graphs of membrane potential vs. time; distinguish between depolarization, repolarization and hyperpolarization.
AP.IC.2: Special senses			
Sight			
Choose a disease causing a homeostatic imbalance to vision. Use a picture as a control, and modify the picture to show how the picture would be seen by an individual with the chosen visual disease. Design a possible medical device that could alleviate the symptom.	Propose hypotheses for how the vertebrate eye first appeared in a common ancestor as a simple organ or clump of cells that detected light and the direction from which it came. Explain the possible adaptive significance of this photosensitivity. Propose one or more evolutionary hypotheses to explain the differences and similarities in the structure and function of vertebrate eyes and molluscan eyes.	Examine binocular vision by performing various eye tests. Identify common defects of the eye (e.g., astigmatism, color blindness) and their common treatments. Investigate a specific neurological effect of aging and explain how this leads to a homeostatic imbalance (e.g., glaucoma, hyperopic). Compare the structure of the vertebrate eye and the molluscan eye. Design a poster using physiological differences between the vertebrate eye and the molluscan eye to explain why mollusks will never suffer the homeostatic imbalance of detached retina.	Trace the pathway of light through the eye. Use microscopes, micrographs, models or illustrations to identify the main structures of the eye, and their functions.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Hearing/balance			
Choose a disease causing a homeostatic imbalance to the sense of hearing. Modify a sound file to illustrate the effects of the damage and suggest possible medical devices that could alleviate the symptoms. Design a device to direct whales from areas of danger (e.g. the site of a major underwater oil well failure). Use the mechanism by which bats capture prey in darkness to design an assistive technology for visual impairment.	Examine the evolutionary origin of the bones involved in hearing in mammals from the earliest chordates.	Explain how the inner ear maintains equilibrium and balance. Investigate a specific neurological effect of aging and explain how this leads to a homeostatic imbalance (e.g., tinnitus).	Use models or illustrations to identify the main structures in the inner, outer, and middle ear. Listen to different tones and identify patterns of hearing ability. Describe sensorineural and conductive hearing pathways.
Taste/smell			
	Design and carry out an investigation to determine how smell and taste are related in the body and how sensory messages to the brain contribute to flavor perception. Propose one or more hypotheses to explain why a dog's sense of smell is much more sensitive than a human's.	Explain how chemoreceptor function is blocked by a chemical such as miraculin or by *Gymnema sylvestre* tea.	Use models, illustrations or slides to identify the anatomical structures related to taste and smell (e.g., taste buds, gustatory cells, papillae, cilia).
AP.IC.3: Endocrine system			
Glands/structures			
		Examine endocrine system stress responses. Analyze the physiological reactions that were experienced during a situation of threat or stress. Identify which aspects of the endocrine system created those reactions.	Use models and/or illustrations to identify the main structures associated with glands and their associated target cells/organs.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Processes			
Critique the medical devices used by diabetics to monitor and treat blood sugar and propose solutions to address any identified flaws.		Analyze patient data to diagnose a hormone imbalance and provide suggestions for treatment.	Draw examples of negative and positive feedback loops. Predict the effect of changes in hormone levels.
Environmental impacts			
Propose one or more technological or engineering solution(s) to control broad-leafed "weeds" without using potential environmental endocrine disruptors.	Explain how environmental endocrine disruptors can lead to an increase in the incidence rate of breast cancer in women in developed but not in developing countries.	Research and prepare a poster for peers identifying where they are exposed to environmental endocrine disruptors in their daily lives.	

Human Anatomy and Physiology continued

AP.T: TRANSPORT
AP.T.1: Blood
AP.T.2: Cardiovascular system
AP.T.3: Lymphatic and immune systems

CONTENT ELABORATION: TRANSPORT

AP.T.1: Blood
Blood is composed of plasma and the formed elements: red blood cells (erythrocytes), white blood cells (leukocytes), and platelets (thrombocytes). The primary functions of blood are transportation, protection and regulation. Plasma, the most abundant component of blood, is the liquid portion that transports dissolved nutrients, waste, hormones, antibodies and proteins throughout the body. Red blood cells carry oxygen used during cellular processes throughout the body. White blood cells identify and protect the body against infectious disease and foreign cells. Platelets bind together when a blood vessel is damaged resulting in blood clot formation.

The major ABO blood types, A, B, AB and O, are determined by the presence or absence of antigens on the surface of red blood cells. An additional antigen is present or absent on the surface of red blood cells determining Rh factor. Blood type antibodies are found in plasma. Processes related to blood include the production of blood cells and platelets, and hemostasis. Homeostatic imbalances are explored. These include, but are not limited to, sickle cell anemia, hemophilia, deep vein thrombosis, leukemia and lymphoma. Investigations are used to understand and explain blood in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

AP.T.2: Cardiovascular system
The cardiovascular system consists of the heart and blood vessels. The heart is mostly comprised of cardiac muscle which is supplied with oxygenated blood by coronary arteries.

The structure of the heart includes four chambers, four valves and major vessels leading to and from the heart. The flow of blood through the heart, pulmonary and systemic circuits should be explored. Blood flows from arteries, to arterioles, to capillaries, to venules, then to veins. In the capillaries, oxygen, nutrients, and chemical messengers diffuse out (leave) and carbon dioxide and other waste products diffuse in (enter). Veins have valves that keep the blood flowing toward the heart.

The primary function of the cardiovascular system is the transport of oxygen, carbon dioxide, hormones, nutrients, waste products and chemical messengers.

Processes involved in the cardiovascular system include the cardiac cycle and cardiac and conductive pathway which is measured by electrocardiograms and blood pressure.

Homeostatic imbalances are explored. These include, but are not limited to, a variety of cardiovascular diseases and structural imperfections of the heart, valves and vessels. Examples include, but are not limited to, myocardial infarction, aneurysm, atherosclerosis, hypertrophic cardiomyopathy, hypo/hypertension and arrhythmias. Investigations are used to understand and explain the cardiovascular system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

AP.T.3: Lymphatic and immune system
The lymphatic system includes lymph, lymphatic vessels, lymph nodes and the immune system. The lymphatic system has multiple, interrelated functions. They include the removal of fluid from tissues, absorption of large fatty acids in small intestines and transport of white blood cells to the lymph nodes. The immune system consists of white blood cells that destroy foreign antigens. Tissue fluid that has entered into lymphatic capillaries becomes lymph. Multiple lymphatic capillaries form lymphatic vessels. As lymph circulates through the body, it passes through multiple lymph nodes. These lymph nodes contain lymphocytes which destroy foreign antigens.

Processes of the lymphatic system include defense through nonspecific and specific resistance. Examples of nonspecific resistance include mechanical barriers such as the skin, enzymes, species resistance and mucous membranes. In specific resistance, antibodies are produced that defend the body against foreign antigens. Memory cells are produced following an infection that allow for possible immunity against a specific antigen upon re-exposure. A comparison of primary versus secondary immune responses can be explored. Homeostatic imbalances are explored. These include, but are not limited to, autoimmune disorders, parasitic diseases, allergies, bacterial versus viral infections and ringworm. Vaccinations provide the body with either long-term protection or short-term protection against many pathogens. Investigations are used to understand and explain the lymphatic system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

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VISIONS INTO PRACTICE: CLASSROOM EXAMPLES

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
AP.T.1: Blood			
		Create a graphic organizer to illustrate the differentiation of stem cells into white blood cells, red blood cells and lymphocytes. Compare and contrast the genes that code for hemoglobin in humans and mice.	Create labeled illustrations or models of the components of whole blood. Identify the structure and function of red blood cells (erythrocytes). Describe the process of hemostasis. Explain the function of blood and each of the components of whole blood.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Blood typing			
Critique available artificial blood products. Design artificial blood products.	Design a process to identify unknown blood types to determine transfusion compatibility or paternity. Propose one or more hypotheses to explain the global distribution of the ABO blood groups in humans.	Investigate the process of agglutination and describe its consequences. Create a global distribution map of the frequency of the ABO blood groups among native, human populations. Prepare blood transfusion guidelines that a medical assistant can use to understand which patients can receive which type(s) of blood and why blood typing is important for blood transfusions. Include the concepts of "universal donor" and "universal recipient".	Identify ABO phenotypes and genotypes. Identify Rh phenotypes and genotypes. Use Punnett squares to explain the inheritance of blood types. Create a labeled illustration or model of blood to explain the relationship between antigens, antibodies and blood type (e.g., ABO/Rh).
Homeostatic imbalances			
	Compare the original distribution of sickle-cell anemia in human populations with the global distribution of malaria. Propose one or more hypotheses to explain the distributions and make predictions based on your hypotheses. **Note:** *Sickle-cell anemia is a disease found among the descendants of people originally from areas where malaria is or has been common. Avoid the misconception that sickle-cell anemia is linked to one particular race.*	Diagnose homeostatic imbalances (e.g., anemia, sickle-cell anemia, leukemia, sepsis) by analyzing laboratory data (e.g., blood sample, patient symptoms, family history). Construct a pedigree of a family history and create a genetic counseling plan to advise the patient and family.	Explain the role of hemoglobin.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
AP.T.2: Cardiovascular system			
Gross anatomy			
Critique available artificial heart and valve products.	Investigate the structures and function of the human heart by dissecting a sheep heart, which is similar in structure and function. Trace the flow of blood through the vessels, valves, and chambers of the heart and explore the role the organ plays in the propulsion of blood through the pulmonary and systemic circuits. Dissect various vertebrate hearts to compare mammalian hearts with those of birds (4-chambered), amphibians (3-chambered) and fish (2-chambered). Trace the flow of blood through the vessels, valves, and chambers of the heart and explore the role the organ plays in the propulsion of blood through the pulmonary and systemic circuits. Use findings to develop an understanding of the function of the 4-chambered heart to support endothermic organisms.	Based on labeled illustrations, explain the components needed for an artificial heart and/or its components.	Create labeled illustrations or models to describe the pathway of blood through the valves, chambers and major vessels of the heart. Create labeled illustrations or models to describe the pathway of blood through the pulmonary and systemic circuits. Identify the functions of the cardiovascular system.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Cardiac histology			
		Describe the relationship between the structure and specialized function of cardiac muscle cells. Create labeled illustrations, models, or written descriptions to differentiate between arteries, arterioles, capillaries, venules and veins in terms of structure and function.	Identify the cells and tissues of the cardiovascular system.
Cardiac output and imbalances			
Analyze data to explain why long-term exposure to microgravity can be dangerous to the cardiovascular system. Propose counter-measures to minimize effects of microgravity. Design a device to clear an occluded artery.	Manipulate and measure cardiac output to investigate the relationship between heart rate, volume and cardiac output. Diagnose homeostatic imbalances by analyzing signs and symptoms, laboratory data, ECG/EKGs and imaging studies. Create an evidence-based treatment plan.	Describe how microgravity can be applied on Earth to treat or prevent circulatory diseases. Diagnose an individual by analyzing an electrocardiogram. Create labeled illustrations or models of congenital cardiovascular defects and explain how they disrupt normal cardiac function.	Identify the components of cardiac output. Explain the relationship between heart rate, volume and cardiac output. Match electrocardiogram (ECG/EKG) waves to events in the cardiac cycle. Describe the features of an electrocardiogram (ECG/EKG) used to identify homeostatic imbalances. Identify homeostatic imbalances of the cardiovascular system.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
AP.T.3: Lymphatic and immune systems			
Immune system			
	Explain how antibiotic resistance arises in a microbial population using insights from an understanding of evolution through natural selection.	Create a public service announcement highlighting the benefits of vaccinations for children, including risks to the population at large. Compare the treatment of bacterial and viral infections. Include concepts of nonspecific and specific resistance.	Create labeled illustrations or models of the cells of the immune system. Explain how the immune system works. Describe the uses for Enzyme-Linked Immunosorbent Assay (ELISA). Identify and describe the structures and functions of the lymphatic system. Create a flowchart to demonstrate the circulation of lymph throughout the body.
Homeostatic imbalances			
	Design an experiment to test the effectiveness of antibacterial products.	Create a community education campaign to increase awareness about the transmission of insect-transmitted diseases, their causes and prevention. Critique the effectiveness of tonsil removal on infection rates. Design a model to demonstrate the spread of a pathogen throughout a population.	Describe the mechanisms of autoimmune responses.

Human Anatomy and Physiology continued

AP.AE: ABSORPTION AND EXCRETION
AP.AE.1: Digestive system
AP.AE.2: Respiratory system
AP.AE.3: Urinary system

CONTENT ELABORATION: ABSORPTION AND EXCRETION

AP.AE.1: Digestive system
The digestive system consists of the gastrointestinal tract (alimentary canal) as well as various accessory organs including the teeth, tongue, salivary glands, liver, gallbladder and pancreas.

The digestive system processes and supplies the molecules needed to sustain the living tissues within the body through the absorption of nutrients. Six major functions of the digestive system include secretion, ingestion, mechanical processing, enzymatic digestion, absorption and excretion. The lining of the digestive system protects surrounding tissues from the mechanical and enzymatic stresses of the digestive process.

Processes of the digestive system include the mechanical and chemical breakdown of food into small molecules which are then absorbed by the digestive tract. Specific actions within the digestive system include mastication, peristalsis, segmentation and the release of hormones and enzymes necessary for digestion. The metabolic functions of the accessory organs play strategic roles in the breakdown of food products, the maintenance of glucose levels within the blood and the regulation of homeostasis in the body. Indigestible material is excreted as waste. Homeostatic imbalances are explored. These include, but are not limited to, conditions such as gallstones, heartburn, ulcers, dehydration, diarrhea, cirrhosis and cancers of the digestive system. Investigations are used to understand and explain the digestive system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

AP.AE.2: Respiratory system
The respiratory system is comprised of the airways, lungs and diaphragm. The airways include the nasal and oral cavities, pharynx, larynx, trachea, bronchi, bronchioles and alveoli. The respiratory system transports and exchanges gases including oxygen and carbon dioxide.

Processes involved in the respiratory system include respiration mechanics and gas exchange. Respiration mechanics is the process by which humans breathe and includes the movement of the diaphragm and pressure-volume relationships. Gas exchange refers to the diffusion of gas across the alveolar epithelium in the respiratory system and capillary endothelium of the cardiovascular system. Lung volumes and capacities can be measured using spirometry. Homeostatic imbalances are explored. These include, but are not limited to, asthma, chronic obstructive pulmonary disease (COPD), tuberculosis, cystic fibrosis and the effects of smoking and pollution. Investigations are used to understand and explain the respiratory system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

AP.AE.3: Urinary system
The urinary system is a regulatory system that helps maintain homeostasis. The structures of the urinary system include the kidneys, ureters, bladder and urethra. Each kidney consists of the renal cortex, medulla and renal pyramids. The functional unit of the kidney is the nephron. The renal pelvis is a funnel-shaped chamber that is connected to the ureter.

The primary functions of the urinary system are excretion, elimination and regulation of blood volume and pressure. Processes of the urinary system include filtration, reabsorption and secretion, which occurs in the nephrons. Urine is normally a clear, yellow, sterile solution but the composition can vary slightly between individuals. Urinalysis is a diagnostic tool for detecting substances and conditions in the body. Antidiuretic hormone (ADH) and aldosterone hormones influence the volume and concentration of urine. Caffeine and alcohol act as diuretics and can lead to short or long-term kidney issues. Homeostatic imbalances are explored. These include, but are not limited to, urinary tract infections, kidney stones, nephritis and acute and chronic kidney disease. Investigations are used to understand and explain the urinary system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

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Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
AP.AE.1: Digestive system			
Propose a redesign of an alimentary canal segment and/or accessory digestive organ. Propose a procedure as a potential cure for cirrhosis or ulcers using tissue engineering techniques. Explore the types of bariatric surgeries and compare their safety and effectiveness to determine whether this is an effective weight-loss solution. Explain the advantages and disadvantages. Research global geographic variation in the prevalence of lactase persistence. Relate this geographic variation in the ability to chemically digest milk sugar to the cultural history of dairy livestock domestication. Consider the timeframe of microevolutionary changes between human populations.	Investigate the relative lengths of the alimentary canal of various vertebrates with differing diets. Propose hypotheses to explain the relationship between relative length and diet. Design models of mechanical and chemical digestion using varied materials. Compare the efficiency of human digestion and ruminant digestion. Assess the claim that probiotic foods are healthy. Provide evidence to support or refute this claim.	Journal daily food choices and relate it to the current USDA Choose My Plate recommendations. Explain how bariatric surgery impacts the digestive system. Explain how hydrochloric acid (HCl) in the stomach aids in digestion and provides protection from pathogens. Prepare a presentation on the importance of symbiotic colonic bacteria.	Trace food from the mouth to the anus and describe what happens in each region. Describe the structure and function of accessory digestive organs. Explain the role of a specific enzyme in the digestive process. Include where it is produced, where it enters the alimentary canal, the pH range in which it works best, the types of molecules it chemically digests and what products the chemical breakdown forms. Distinguish mechanical from chemical digestion. Identify the regions of the stomach and their functions. Identify tissue and cell types in digestive and accessory organs using microscopes, slides, micrographs, models or illustrations.
AP.AE.2: Respiratory system			
	Design a model to show how cold/flu impacts respiratory function. Use the model to investigate how various remedies alleviate symptoms.	Explain mammalian (including human) respiration by comparing it to the respiratory anatomy and physiology of the other major vertebrate groups (e.g., cephalochordates/urochordates, fish, amphibians, amniotes).	Identify sections of the respiratory tree by histological slides/images. Explain how the structure in each portion of the respiratory tree supports its function. List the normal respiratory volumes. Explain what factors alter respiratory volumes. Name muscles used for inspiration and expiration.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
Obstructive vs. restrictive disease			
	Investigate factors which alter respiratory volumes. Compare breathing in obstructive and restrictive diseases (e.g., simulate obstructive disease by wrapping a belt around the chest and tightening appropriately, simulate restrictive disease by pursing lips around a straw). Collect data on respiratory volumes during obstructive and restrictive respiratory disorders (e.g., use a tape measure to measure the thoracic cavity as an estimate of volume).	Interpret spirometry data and match it to the appropriate "patients"; normal, asthmatic, smoker, athlete. Provide evidence to support your claim.	
Respiratory health and the environment			
Design an action plan to improve the air quality in an area with low air quality (e.g., construction dust in a building). Determine the design specifications of a face mask to filter fine particulate matter (PM 2.5 particles) resulting from the combustion of fossil fuels.	Investigate local air quality and asthma or other pulmonary disease rates. Formulate an argument for how the air quality in an area impacts local respiratory health.	Explore asthma rates, pollution levels and ozone levels, globally. Create a poster or other graphic comparing the size of PM 2.5 particles generated by combustion of fossil fuels to the size of particles that can be diffused by the surfaces of the respiratory system (including the size of red blood cells).	Explain the physiological effects and damages caused by PM 2.5 particles generated by the combustion of fossil fuels.
Exercise and respiration			
Design a device to improve the respiratory function in athletes.	Perform an investigation to compare pre- and post- exercise data (e.g., breathing rate, depth, tidal volume).		Differentiate between tidal volume and breathing rate. Explain how to determine breathing rate and depth.

Designing technological/engineering solutions using science concepts	Demonstrating science knowledge	Interpreting and communicating science concepts	Recalling accurate science
AP.AE.3: Urinary system			
Design a device that serves as a "mini dialysis" machine to be used in patients with renal failure. List and discuss the limitations.	Design a model using dialysis tubing and some common solute to demonstrate the movement of wastes from interstitial fluid to the renal tube. Match representative urine lab values (concentrations) with mock patient scenarios for a condition (e.g., high ADH, dehydration, excess coffee, urinary tract infection, diuretics). Create a treatment plan for the patient.	Illustrate filtration, secretion and reabsorption of ions/molecules in the kidney. Explain the relationship between the renal system and other organ systems (e.g., vascular). Include complications of renal failure. Interpret lab values to determine what ions/proteins need to be altered during dialysis. Create a pamphlet that explains the impact of diet on blood chemistry and how that affects kidney function, especially in those on dialysis. Compare the functions of current hemodialysis machines with the actual kidneys. Illustrate or describe the roles of osmosis and diffusion in the process of urine formation. Explain what lab values you would expect in various patient scenarios (e.g., infection, dehydration). Kangaroo rats live in the Mojave Desert of the U.S. Predict how the relative dimensions of their nephrons compare with those of humans. Justify the prediction.	Trace the formation of urine through the processes of osmosis and diffusion. Describe the basic physiological processes accomplished by the nephron (filtration, reabsorption, secretion). Describe the process by which the body eliminates excess fluids. Identify normal urine concentrations. Illustrate or describe the roles of osmosis and diffusion in the process of urine formation. Explain how molecules/hormones influence the body's hydration status. Identify the impacts of drinking too much water (i.e., hyperhydration). Describe the gross and histological structure of the urinary bladder. Relate the structure of the urinary bladder to its function.

Human Anatomy and Physiology continued

AP.R: REPRODUCTION
AP.R.1: Reproductive system

CONTENT ELABORATION: REPRODUCTION

AP.R.1: Reproductive system
The reproductive system is comprised of internal and external organs and hormones. The ovaries and testes produce gametes that fuse to form a zygote, a single cell that develops into an embryo and eventually an adult. A comparison of male and female anatomy should be explored. The female body has the function of providing protection and nourishment for the developing fetus until birth. If all is successful, a new generation of offspring will occur.

The processes of the reproductive system include oogenesis, spermatogenesis and fertilization. Additional processes can include lactation and menstruation. Homeostatic imbalances are explored. These include, but are not limited to, infertility, chromosomal disorders, endometriosis, cancer, Human Papillomavirus (HPV), and sexually transmitted diseases (STD's). Investigations are used to understand and explain the reproductive system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

Note: *At this level, a detailed description of embryological development is not required. The focus is on the structure and function of the reproductive organs.*

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AP.R.1: Reproductive system			
Design an artificial womb (ectogenesis) that could support embryonic life.	Examine how environmental variables can impact sea urchin fertilization.	Develop a visual graphic with a timeline indicating the evolution of reproductive physiology in mammals from egg laying monotremes, marsupials and then placental mammals. Display the current global distribution of monotreme, marsupial and placental mammals. Propose one or more hypotheses to explain these observed distribution patterns. Interpret information from a case study to discuss the misconception that all menstrual cycles last 28 days. Design a poster or similar graphic to inform peers of the global, human population over the last 5,000 years.	Identify the structures of the male reproductive system and the functions of each structure. Identify the structures of the female reproductive system and the functions of each structure. Explain the pathway of a gamete through each reproductive system. Compare the processes of oogenesis and spermatogenesis.