## Biology
### Syllabus and Model Curriculum

**Course Description:** Biology is a high school level course, which satisfies Ohio Core science graduation requirements as required by section 3313.603 of the Ohio Revised Code that requires three-unit course with 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.

### Science Inquiry and Application

*During the years of grades 9 through 12 all students must use the following 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**
- Use technology and mathematics to improve investigations and communications;
- Formulate and revise explanations and models using logic and evidence (critical thinking);
- Recognize and analyze explanations and models; and
- Communicate and support a scientific argument.

### Course Content

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

#### Heredity
- Cellular Genetics
- Structure and function of DNA in cells
- Genetic mechanisms and inheritance
- Mutations
- Modern Genetics

#### Evolution
- Mechanisms
  - Natural Selection
  - Mutation
  - Genetic drift
  - Gene flow (immigration, emigration) and mutation
  - Sexual selection
  - History of life on Earth -
- Diversity of Life
  - Speciation and biological classification based on molecular evidence
  - Variation of organisms within a species due to population genetics and gene frequency

#### Diversity and Interdependence of Life
- Classification systems are frameworks created by scientists for describing the vast diversity of organisms indicating the degree of relatedness between organisms.
- Ecosystems
  - Homeostasis
    - Carrying capacity
    - Equilibrium and disequilibrium
Cells

- Cell Structure and Function
  - Structure, function and interrelatedness of cell organelles
  - Eukaryotic cells and prokaryotic cells

- Cellular Processes
  - Characteristics of life regulated by cellular processes
  - Photosynthesis, chemosynthesis, cellular respiration
  - Cell division and differentiation

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), this topic focuses on the explanation of genetic patterns of inheritance.

By the beginning of 10th grade, students should know that living things are a result of one or two parents, and traits are passed on to the next generation through both asexual and sexual reproduction. Additional prior knowledge from middle school is that traits are defined by instructions encoded in many discrete genes and that a gene may come in more than one form called alleles. In grade 10, the explanation of genes is expanded to include the following concepts. Life is specified by genomes. Each organism has a genome that contains all of the biological information needed to build and maintain a living example of 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” 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. An altered gene may 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 environment. 5B/H4** (AAAS, pg 109, 5B:9-12#5) Gene mutations when they occur in gametes can be passed on to offspring. Genes code for protein. The sequence of DNA bases in a chromosome determines the sequence of amino acids in a protein.

“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. Different genes are active in different types of cells, influenced by the cell’s environment and past history.” (AAAS)

In grade 10, Mendel’s Laws of Inheritance (grade 8) are interwoven with current knowledge of DNA and chromosome structure and function to build toward basic knowledge of modern genetics. In grade 8, comparison of asexual and sexual reproduction described advantages and disadvantages of each type to a population. Grade ten reinforces grade 8 knowledge that sorting and recombination of genes in sexual reproduction and meiosis specifically results in a variance in traits of the offspring of any two parents and explicitly connects the knowledge to evolution.

Mendel’s work was introduced in grade 8 but the gene interactions described in grade 8 were limited primarily to dominance and co-dominance traits. In high school genetic mechanisms both classical and modern including incomplete dominance, sex-linked traits, goodness of fit test (Chi-square) and dihybrid crosses are investigated through real-world examples. Genes that affect more than one trait (pleiotropy), traits affected by more than one gene (epistasis), and polygenic traits can be introduced using simple real world examples. Additionally genes that modify or regulate the expression of another gene in should be included in explorations at the high school level. Dihybrid crosses can be used to explore linkage groups. Modern genetics techniques, such as cloning should be explored in this unit.

Expectations for Learning: Cognitive Demands

This section provides definitions for Ohio’s science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science.

Expectations for Learning: Visions into Practice

This section provides examples of tasks that students may perform; this includes guidance for developing classroom performance tasks and assessments. It is not an all inclusive checklist of what should be done, but is a springboard for generating innovative ideas.

Develop a timeline from Mendel, Darwin and Wallace’s work to the present day.
Design and implement investigations to test the affect of low doses of different common chemicals (boric acid, nail polish remover) on the development (from fertilized egg to adult) of an organism (fast plant seeds). Represent the data in a way that demonstrates the relationship, if any, between the chemical and changes in the development pattern. Explain how the investigation is similar to, or different from, the processes that occur in the natural environment.

**Instructional Strategies and Resources**: This section provides additional support and information for educators. These are strategies for actively engaging students with the topic and for providing hands-on minds-on observation and exploration of the topic, including authentic data resources for scientific inquiry, experimentation and problem-based tasks that incorporate technology and technological and engineering design. Resources selected are printed or web-based materials that directly relate to the particular Content Statement. It is not intended to be a prescriptive list of lessons.

The National Institute of the Health provides a time line of the milestones in genetics. Stories, archival images, and original scientific publications tell the historical story of genetic discoveries. Students can trace how new understandings about the transmission of traits developed new questions that led to new discoveries. One major milestone is the Human Genome Project. DNA Learning Center features an interactive site that provides detailed background knowledge on how genomes are developed and used for research.

Mendelian Genetics provides clear explanations for basic genetics; this link connects to an explanation and example of Chi-square.

Cold Spring Harbor Laboratory’s Dolan DNA Learning Center provides DNA Molecules for models that help to illustrate some of the harder to represent concepts associated with DNA. Scroll down the page to the More 3-D Animation Library.

**Common Misconceptions**
The University of Utah provides information about misconceptions related to cloning.

Weber State University provides a list for misconceptions in biology. Scroll down to Standard II to address misconceptions about pattern of inheritance.

**Diverse Learners**

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Content Elaboration:  
Evolution

Building on elementary school concepts, living things can only survive when their basic needs are met, fossil (grade 4) and middle school concepts of biodiversity (as part of biomes) and speciation (8th grade) biological evolution is explored. 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. The study of evolution should include Modern Synthesis, the unification of genetics and evolution and historical perspectives of evolutionary theory. The study of evolution should include gene flow, mutation, speciation, natural selection, genetic drift, sexual selection, and Hardy Weinberg’s Law.

The basic idea of biological evolution is that the Earth’s present-day species descended from earlier, common ancestral species. Modern ideas about evolution provide a natural explanation for the diversity of life on Earth as seen in the fossil record, in the similarities of existing species, and modern molecular evidence. From a long-term perspective, evolution is the descent with modification of different lineages from common ancestors. From a short-term perspective, evolution is the ongoing adaptation of organisms to environmental challenges and changes.

Different phenotypes result from new combinations of existing genes or from mutations of genes in reproductive cells. Populations evolve over time. Evolution 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 with the specific phenotype.

Recent molecular sequence data generally support earlier hypotheses regarding lineages of organisms based upon morphological comparisons.

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.

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Instructional Strategies and Resources

Manipulate variables (e.g., distribution of traits, number of organisms, and change in environmental conditions) in a simulation that represents natural selection in terms of how changes in environmental conditions can result in selective pressure on a population of organisms.

Analyze the data to determine the relationship, if any, between the environmental changes and the population. Explain how each part of the simulation is similar to, or different from, the process of natural selection.

University of Colorado’s PhET provides an interactive simulation of natural selection for a population of rabbits. Environmental factors can be altered and mutations introduced to show how the population would change over time.

Annenberg’s Rediscovering Biology: Molecular to Global Perspectives, Session 3, Evolution and Phylogenetics is a tutorial for teachers on some of the current advances in Biology

The National Science Teachers Association offers a position paper on the Teaching of Evolution.

Online course in evolutionary biology for teachers is provided by the Public Broadcasting System: Evolution.
**Common Misconceptions**  
The Southern Nevada Regional Professional Development Center provides a list of common student naïve conceptions about evolution.

**Diverse Learners**

**Classroom Portals**  
http://www.learner.org/resources/series126.html#  
The Annenberg Media series “Teaching High School Science” is a six video program that highlights a variety of classroom activities that foster inquiry-based leaning.
### 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) and from middle school (biomes and biogeochemical cycles), this topic 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 great diversity of organisms and ecological niches they occupy result from more than 3.5 billion years of evolution. Some ecosystems can be reasonably persistent over hundreds or thousands of years. Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change as geological or biological conditions vary. Misconceptions about population growth capacity, interspecies and intra-species competition for resources, what occurs when a species immigrates to or emigrates from ecosystems are appropriate to address at this grade level.

Classification systems are frameworks created by scientists for describing the vast diversity of organisms, indicating the degree of relatedness between organisms. Recent molecular sequence data generally support earlier hypotheses regarding lineages of organisms based upon morphological comparisons. Both morphological comparisons and molecular evidence should be used to describe biodiversity. (Cladograms can be addressed)

Organisms transform energy (flow of energy) and matter (cycles of matter) as they survive and reproduce. The cycling of matter and flow of energy occurs at all levels of biological organization, from molecules to ecosystems. The study of food webs starts in the elementary grades. The study continues in the middle grades with the flow of energy through organisms. In high school the concept of energy flow as unidirectional in ecosystems is explored.

Grade appropriate mathematical graphing and algebraic knowledge should be used to explain concepts of carrying capacity and homeostasis within biomes. Simple mathematical models should include exponential growth model and the logistic growth model. The simplest version of the logistic growth model is \[ dN/dt = rN \left( \frac{K-N}{K} \right) \], the only new variable added to the exponential model is \( K \) for carrying capacity.

**Note:** Exponential growth equation in simplest form, change in population size \( N \) per unit time \( t \) is a product of \( r \) (the per capita reproductive rate) and \( N \) (population size).

**Note:** Carrying capacity is defined as the population equilibrium sized when births and deaths are equal, and hence \( dN/dt = 0 \).

**Note:** Constructing food webs/food chains to show interactions between organisms within ecosystems was covered in upper elementary school and middle school, constructing them as a way to demonstrate content knowledge is not appropriate for this grade. Students may use these diagrams to help explain real-world relationships or events within an ecosystem, but not to identify simple trophic levels, consumers, producers, predator-prey, and symbiotic relations.

### Expectations for Learning: Cognitive Demands

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Construct a model to exemplify biomagnifications in an ecosystem such as mercury in Lake Erie. Include a quantification of the distribution and buildup of the potentially damaging molecule that was introduced into the ecosystem. Within the model, predict and explain why the consequences occur at each trophic level as the relative concentration of the chemical increases. Include in your justification the changes in the number of organisms at each trophic level, matter cycling, and energy transfer from one level to another.

### Instructional Strategies and Resources

These are strategies for actively engaging students with the topic and for providing hands-on minds-on observation and
exploration of the topic, including authentic data resources for scientific inquiry, experimentation and problem-based tasks that incorporate technology and technological and engineering design. Resources selected are printed or web-based materials that directly relate to the particular Content Statement. It is not intended to be a prescriptive list of lessons.

Examine wildlife populations in Ohio like the bald eagle and the beaver. The Ohio Department of Natural Resources provides data on their population over the years. Examines the factors that have impacted the carrying capacity.

The Southern Nevada Regional Professional Development Center provides a tutorial, which explains the links between classification systems and evolution.

Common Misconceptions
Binghamton University provides a general list for of naïve concepts for life science called Overcoming Ecological Misconceptions.

Diverse Learners

Classroom Portals
http://www.learner.org/resources/series126.html# The Annenberg Media series “Teaching High School Science” is a six video program that highlights a variety of classroom activities that foster inquiry-based learning.

Content Elaboration:

Cells
Building on knowledge from middle school (cell theory), 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, cell division and differentiation are studied at this grade level. Additionally, cellular organelles studied are cytoskeleton, Golgi complex and endoplasmic reticulum.

From about 4 billion years ago to about 2 billion years ago, only simple, single-celled microorganisms are found in the fossil record. Once cells with nuclei developed about a billion years ago, increasingly complex multicellular organisms evolved.

Every cell is covered by a membrane that controls what can enter and leave the cell. In all but quite primitive cells, a complex network of proteins provides organization and shape. Within the cell are specialized parts for the transport of materials, energy transformation, protein building, waste disposal, information feedback and movement. In addition to these basic cellular functions, most cells in multicellular organisms perform some specific functions that others do not.

A living cell is composed of a small number of elements, mainly carbon, hydrogen, nitrogen, oxygen, phosphorous and sulfur. Carbon, because of its small size and four available bonding electrons, can join to other carbon atoms in chains and rings to form large and complex molecules. The essential functions of cells involve chemical reactions that involve water and carbohydrates, proteins, lipids, and nucleic acids. A special group of proteins, enzymes enable chemical reactions to occur within living systems.

Cell functions are regulated. Complex interactions among the different kinds of molecules in the cell cause distinct cycles of activities, such as growth and division. Most cells function within a narrow range of temperature and pH. At very low temperatures, reaction rates are slow. High temperatures and/or extremes of pH can irreversibly change the structure of most protein molecules. Even small changes pH can alter how molecules interact.

The sequence of DNA bases on a chromosome determines the sequence of amino acids in a protein. Proteins catalyze most chemical reactions in cells. Protein molecules are long, usually folded chains made from combinations of the 20 typical amino-acid sub-units found in the cell. The function of each protein molecule depends on its specific 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: The concept of the cell and its parts as a functioning system is more important than memorizing parts of the cell.

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<td>Investigate the effect of different chemicals on the growth of algal colonies; use mathematics to explain why even under ideal situations the colonies cannot continue exponential growth.</td>
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<tr>
<td>Plan and design an investigation to determine the factors that affect the activity of enzymes on their substrates.</td>
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<td>Observe a variety of cells under a microscope with optical enhancements to alter the image for greater detail. Here are three inexpensive optical enhancements methods that can dramatically alter the image of a simple microscope. What additional information can be found by altering the images?</td>
</tr>
<tr>
<td>Make yogurt and examine the role of bacteria in its production. Determine what types of bacteria are used and how they interact with one another. How does this interaction impact the environment of the batch of yogurt (pH levels and impact on milk proteins)?</td>
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### Common Misconceptions


### Diverse Learners


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Chemistry
Syllabus and Model Curriculum

Course Description: Chemistry is a high school level course which satisfies Ohio Core science graduation requirements, as required by section 3313.603 of the Ohio Revised Code, which require inquiry-based courses with laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information. Pacing is determined at the local level.

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.

Students engage in investigations 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.

Science Inquiry and Application
During the years of grades 9 through 12 all students must use the following 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;
- Use technology and mathematics to improve investigations and communications;
- Formulate and revise explanations and models using logic and evidence (critical thinking);
- Recognize and analyze explanations and models; and
- Communicate and support a scientific argument.

Course Content

Classifying Matter
- Scientific measurement and communications
- Distinguishing characteristics of different materials

Structure of Matter
- Atomic structure
  - Evolution of atomic models/theory
  - Electrons
  - The nucleus
- Periodic Table
  - Properties
  - Trends

Interactions of Matter
- Chemical Bonding
  - Ionic and Covalent
  - Nomenclature
- Chemical Reactions
  - Balancing
  - Kinetics
  - Equilibrium
  - Acids/Bases
- Stoichiometry
  - Molar calculations
Content Elaboration

Classifying Matter

Effective communication in science requires that matter be described using skills which accurately quantify, qualitatively identify, and thereby categorize materials. These skills entail using SI (System International), or MKS (meters, kilograms, and seconds) and CGS (centimeters, grams, and seconds) metric systems, significant digits or figures, scientific notation, standard units, derived units, error analysis, dimensional analysis, etc. In essence, communicating findings using numbers to describe and distinguish specific characteristics of various materials is the standardized language.

- **Scientific Measurements**

A property of an object is described as a qualitative (what is it?), or quantitative (how much is present?), characteristic of how the object interacts with other objects, or how the object is perceived – that is how the object interacts with our senses. Thus, the use of a measuring instrument provides more reliable information about an object’s properties than our senses alone, though a measurement is never exact; there is always some error associated with the measurements. Scientific measurements should always be reported in metric units – this is universal for communicating science information using standardized language.

When defining time intervals, it is convenient to think about three domains of magnitude in size and time (where distance is in meters and time is in seconds); the macro (human) domain, the cosmic domain and the atomic and subatomic domains. The macro (human) domain (distance and time larger than about $10^{-6}$ and smaller than about $10^{10}$) corresponds roughly with what can be perceived and measured with either human senses or simple instruments (e.g., optical microscopes and telescopes). The cosmic domain (distance larger than about $10^{10}$), and requires instruments or procedures that depend on long chains of reasoning to understand how they work. Similarly, the atomic and subatomic domains (distance and time $<10^{-6}$ and $<10^{-14}$ respectively) are tiny and requires a great deal of knowledge to understand the measurement instruments used to work in this domain (Heller & Stewart, 2010).

- **Distinguishing characteristics of different materials**

There are four most recognized states of matter: solid, liquid, gas and plasma. There is also Bose-Einstein condensation where the atoms, when subjected to temperatures a few billionths of a degree above Absolute zero, all coalesce to lose individual identity and become a “super atom.” Just as plasmas are super-hot atoms, Bose-Einstein condensates are the opposite, super-cold atoms. (ref. Teacher note)

The atomic-molecular theory is used to explain the behavior, or distinguishing characteristics, of matter in the known states. Physical properties of materials determined by the strength of the attractions between the particles from which the materials are composed. For example, the (kinetic) energy of the particles causes the particles which compose solids to vibrate in place, yet the distance between them does not change or increase – thus, solids exhibit rigidity and strength.

Teacher note: The advancement of technology makes it possible to extend the boundaries of current knowledge and understanding. Consequently, Bose-Einstein condensates were only recently created (1995), although predicted over 80 years ago. Detailed instruction is not required at this grade level, just as it is not with plasmas. This information is strictly for recognition that new discoveries are occurring and extending the realm of current understanding and notably in science.

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### Course Content

**Structure of Matter**

- **Atomic structure**
  - Evolution of atomic models/theory
  - Electrons
  - The nucleus
- **Periodic Table**
  - Properties
  - Trends

### Content Elaboration

**Structure of Matter**

Matter can be represented in multiple ways, the macroscopic level, the atomic-molecular level, or as symbolic. Real-world settings provide a setting for observable representations of matter. Atomic-molecular representations are usually provided by visual animations, whereas formulas, equations, physical models as manipulatives, or even elemental symbols represent matter symbolically. Each provide a different type of information about materials and can be used according to the appropriate representation needed to conceptualize the structure and function of matter and its interactions, or changes.

- **Atomic structure**

  Building upon instruction at the middle school level, all atoms consist of three subatomic particles, protons, neutrons and electrons. An atom’s electron configuration is determined by the number of positive protons in the nucleus and so defines the element. Neutrons have no charge and have approximately the same mass as protons. The protons and electrons are equal in number for neutral atoms.

  Atoms are so small that they are difficult to study directly; atomic models are constructed to explain experimental data on collections of atoms. Different mental models are useful at the atomic scale (~10^-10 m) and subatomic scale (~10^-15 m). At the atomic scale, the small-particle model of matter is useful for explaining the physical properties of substances, such as the state (solid, liquid, or gas) of a substance at room temperature. There are several early experiments that were used to characterize the atom. Significant experiments include Thompson’s study of electrical discharges in cathode-ray tubes, and Rutherford’s experiment on α-particle bombardment of metal foil. Bohr later proposed a new model of the atom that focused on electrons, from which Schrodinger developed an even more accurate model, electron cloud model.

  Although Bohr’s simple shell model is not the currently accepted best representation of atomic structure, it is an extremely useful model that can be used qualitatively to explain and predict many atomic properties and trends in atomic properties; and it forms a basis for understanding the relative energies of electrons in an atom. In particular, the arrangement of electrons into shells and sub-shells is reflected in the structure of the periodic table and in the periodicity of many atomic properties. Understanding how the shell model is consistent with the experimental data is a key learning goal, rather than the memorization of the patterns of electron configurations. Introductory knowledge about the quantum mechanical model as the currently accepted model for the atom is important for scientific literacy, as it describes, explains, and predicts subatomic interactions.

  As for electrons, the electron orbitals represent the probability (a “cloud”) of finding an electron in a region of space, as much of the space surrounding the nucleus is empty space. Therefore, it is not possible to predict exactly where electrons are located. Based on the current atomic model, electrons can be considered as clouds of electron density or probability, rather than as particles orbiting the nucleus. Nevertheless, the exact energies of electrons can be measured, and regions where electrons are
most likely located can be defined. Electrons have definite energy levels, with no values in between. They usually occupy the lowest available energy orbital. When an electron moves from one energy level to another, it emits or absorbs a photon that has energy equal to the energy difference between the levels. The energy levels of electrons are different for each element. Consequently, each element has a unique emission or absorption spectrum. It should be noted that being aware of the Quantum Mechanical Model of the atom as the currently accepted model for the atom is important for science literacy but details should be reserved more advanced study.

- Periodic Table

The modern version of the periodic table is organized in order of increasing atomic number. The elements were originally placed in the table based on repeating patterns, a result of the number of electrons and specifically valence electrons. Thus, today, the placement of an element on the periodic table can be predicted based on its properties, which gives rise to the periodic law; accordingly, groups of elements exhibit similar properties with predictable variations, and rows of elements have predictable trends – all based on similar valence electron configurations. What emerges from these patterns are systematic variations called periodic trends: atomic radii, ion sizes, ionization energies, electron affinities and electronegativities, etc. Subsequently, elements are able to be classified broadly as metals, nonmetals and metalloids, as has been previously taught in middle school. Boundaries for this topic are that patterns for the transition elements, lanthanide and actinide series be reserved for more advanced study.

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Investigate the variations and similarities between regular table sugar, high fructose corn syrup, Stevia, Aspartame (Equal®), saccharin (Sweet n’ Low ®), and sucralose (Splenda®), and Agave; make a claim for which sweetener is better, or healthier, or most damaging for human consumption. Present your findings in multiple formats. Variation for this project could be done with oils (e.g. canola, coconut, vegetable, etc.).

Design an investigation to substantiate, or negate, the claims of a commercial product (i.e., ionic - tourmaline (a mineral which is said to emit more quick-drying ions) hair dryer, or shake weight dumbbell, a type of strong-bond glue). Determine function of, intent of, and any potential bias with the product. Present your findings in multiple formats.

Instructional Strategies and Resources: This section provides additional support and information for educators. These are strategies for actively engaging students with the topic and for providing hands-on minds-on observation and exploration of the topic, including authentic data resources for scientific inquiry, experimentation and problem-based tasks that incorporate technology and technological and engineering design. Resources selected are printed or web-based materials that directly relate to the particular Content Statement. It is not intended to be a prescriptive list of lessons.

http://www.bbc.co.uk/learningzone/clips/alkali-metals/4407.html - Video provides information about the reactivity of elements within a group/family.

http://www.igcar.ernet.in/nuclear/atomic_nucleus.htm - Website provides details regarding atomic structure.

http://www.aboutnuclear.org/view.cgi?fC=The_Atom,Structure_of_the_Atom - Website provides details regarding atomic structure.

An interactive game, The Periodic Table of Data, is provided to help students learn what type of information is provided on the Periodic Table.

Common Misconceptions

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structure.

An interactive game, The Periodic Table of Data, is provided to help students learn what type of information is provided on the Periodic Table.


Diagnoser Tools: Instructional Tools in Mathematics and Science - a web site that provides diagnostic instructional tools for middle and high school teachers and students. These tools, which include web-served assessments, are aligned with National Standards and Benchmarks in science and mathematics. Resources in this project have been developed and tested by teachers and are based on research into the teaching and learning of math and science.

The student thinks that something other than the number of protons identifies the atom.
- The student thinks that the number of neutrons identifies the atom.
- The student thinks that the total number of nuclear particles (protons and neutrons) identifies the atom.
- The student thinks that the number of electrons identifies the atom or that the number of protons and electrons identifies the atom.
- The student thinks that all atoms of the same element have to have exactly the same number of protons, neutrons and electrons.

The student thinks that every different substance (CO₂, H₂O, salt, ...) is made from atoms of that substance and does not understand that all substances come from the same set of elements.

C³P Project, "Comprehensive Conceptual Curriculum for Physics"
http://phys.udallas.edu/C3P/Preconceptions.pdf

- There is only one correct model of the atom.
- Electrons in an atom orbit nuclei like planets orbit the sun.
- Electron clouds are pictures of orbits.
- Electrons can be in any orbit they wish.
- Hydrogen is a typical atom.
- The wave function describes the trajectory of an electron.
- Electrons are physically larger than protons.
- Electrons and protons are the only fundamental particles.
- Physicists currently have the "right" model of the atom.
- Atoms can disappear (decay).

Substances which are not hard and rigid cannot be solids (Stavy & Stachel, 1985).


Diverse Learners

Classroom Portals
The World of Chemistry is appropriate for students taking high school or college chemistry, from introductory to advanced levels, and is easily applicable to different teaching approaches.

Design an investigation to show that the volume of any liquid sample, when divided by its mass, is a constant; present your data analysis in multiple formats.

Water responds differently to extreme temperatures than most liquids; consider the three states of water and design an investigation to determine the conditions necessary for each state (i.e., temperature & pressure); investigate the implications of these factors for life on planet Earth. Present your findings in multiple formats.

Instructional Strategies and Resources: This section provides additional support and information for educators.
These are strategies for actively engaging students with the topic and for providing hands-on minds-on observation and exploration of the topic, including authentic data resources for scientific inquiry, experimentation and problem-based tasks that incorporate technology and technological and engineering design. Resources selected are printed or web-based materials that directly relate to the particular Content Statement. It is not intended to be a prescriptive list of lessons.

http://www.colorado.edu/physics/2000/bec/
http://www.fortunecity.com/emachines/e11/86/bose.html


Reactions in Chemistry is an eight-part workshop for the professional development of high school chemistry and physical science teachers. (www.learner.org)

Atoms and Molecules is a program that deals with teaching the very first steps of chemistry. It introduces the basic building blocks — the atoms — which, through their properties, periodicity and binding, form molecules. (www.learner.org)

Common Misconceptions

- a failure to distinguish between measurements of mass and volume;
- a lack of procedural knowledge of ways to measure mass and volume;
- a failure to distinguish among different measures of size such as volume, surface area, and perimeter.

Big means the same thing as heavy. (Horton, 2007)

There are 100 cm$^3$ in 1 m$^3$ (Horton, 2007)

Diverse Learners

Classroom Portals

Macro to Micro Structures is a program that deals with the conceptualization of micro processes and environments. It involves teaching chemistry through macro phenomena, which can be observed, and micro processes, which occur on the molecular level, and can only be imagined. (www.learner.org)

Course Content

Interactions of Matter
- Chemical Bonding
  - Ionic and Polar/Covalent
  - Nomenclature
- Chemical Reactions
  - Balancing
  - Kinetics
  - Equilibrium
  - Acids/Bases
- Stoichiometry
  - Molar calculations
  - Limiting reagents, chemical composition, empirical and molecular formula
  - Concentration of solutions
- Conservation
  - Mass
  - Energy
- Nuclear Chemistry
  - Radioisotopes
  - Nuclear Energy
**Content Elaboration**

**Interactions of Matter**

The interactions that matter undergoes can be studied from an intramolecular perspective, as well as an intermolecular perspective, and is directly connected to the structure of the atoms from which the matter is composed. From the intramolecular perspective, study shows how atoms come together to form various materials and how those materials respond under various conditions. From the intermolecular perspective, materials behave in varied ways according to characteristic properties. For example, some atoms lose electrons thereby differentiating a material from one which is inert and does not lose electrons. Some atoms have bonding structures that make materials very strong and therefore useful in situations requiring hard and strong structures. Some materials have atomic structures that only allow them to be diffused, while others have high flow capacity.

These changes, which occur at either the atomic level and/or the subatomic level, incur variation in the energy associated with each constituent. Energy changes that occur at the subatomic level require and result in tremendous energy changes, as is discussed in more detail later. Societal implications for such changes are vast and the study, thereof, potentially provides students with a broader perspective; subsequently, their knowledge is applied to not only immediate experiences, but to global conditions affecting Earth and its future well-being.

**Chemical Bonding**

An atom’s electron configuration, particularly the outermost elections, determines how the atom can interact with other atoms. Atoms form bonds to other atoms by transferring or sharing electrons. Therefore, atoms can bond to form molecules, ionic lattices, network covalent structures or materials with metallic properties. Each of these types of structures has different, yet predictable, properties that depend on the identity of the elements and the types of bonds formed. These bonds are called chemical bonds and are the strong electrostatic forces of attraction that hold the atoms together in a unit.

Ionic bonds involve the attraction between two oppositely charged ions, typically a positively charged metal ion and a negatively charged nonmetal ion. Covalent bonds typically involve at least two electrons shared between the bonding electrons in nonmetal atoms. Covalent bonding can result in the formation of structures ranging from small molecules to large molar mass biopolymers and three-dimensional lattices. Polar covalent bonding forms between two atoms with different electronegativities; the magnitude of the polarity of the bond depends on the electronegativity difference and the distance between the atoms (bond length).

Covalent bonds, ionic bonds and metallic bonds are distinct from typical intermolecular interactions. Covalent chemical bonds can be modeled as the sharing of one or more pairs of valence electrons between two atoms in a molecule. Electronegativity can be used to reason about the type of bonding present between two atoms. The extent to which this sharing is unequal can be predicted from the relative electronegativities of the atoms involved; the relative electronegativities can generally be understood through application of the shell model and Coulomb’s law. The Lewis structure model, combined with valence shell electron pair repulsion (VSPER), can be used to predict many structural features of covalently bonded molecules and ions. Common arrangement pairs of bonding electrons to consider in those structural features include, linear, trigonal planar, tetrahedral, trigonal bipyramidal and octahedral. Also included here is the mixing of the native atomic orbitals to form special orbitals for bonding, hybridization. Ionic bonding is used to describe the strong Coulombic interaction between ions in an ionic substance. The bonding in metals is characterized by delocalization of valence electrons.

As previously stated, the configuration of atoms in a molecule determines the molecule’s properties. Shapes are particularly important in how large molecules interact with others. The shape and polarity of the molecules of a substance determine the relative strength of its intermolecular forces. There are several types of intermolecular forces, including the following: London dispersion forces, dipole-dipole and hydrogen bonding.

When elements bond, they form compounds that are named in systematic ways according to the corresponding atom’s oxidation number. Oxidation numbers, as a general rule, are assigned to a bonded atom as the charge that it would have if the electrons in the bond were assigned to the atom of the more electronegative element. For example, the oxidation numbers of the atoms in NaCl are equal to their ionic charges. Na+ has an oxidation number of +1, and Cl -1. It should be noted that oxidation numbers are written behind the sign (+, or -). Other specific rules apply to naming acids and compounds that are binary ionic, ternary ionic, and binary molecular. The suffixes –ite, or –ate, relate to the number of oxygen atoms in the ion. For
example, an ion whose name ends in –ite has one less oxygen atom than the ion that ends in ate; and a prefix of per- indicates more oxygen atoms than the ion normally can bond. Neither suffix, however, indicates the specific number of oxygen atoms in the ion. The names of acids usually come from the name of the anion (e.g., sulfuric acid is thusly name for the sulfate anion in di-hydrogen sulfate).

Carbon chemistry and the detailed study on the molecules responsible for life are reserved for more advance study.

- **Chemical Reactions**

Chemical reactions involve electrons; nuclear reactions can involve only changes in the nucleus. Neutrons have little effect on how an atom interacts with other atoms, yet the number of neutrons does affect the mass and stability of the nucleus. Atoms with the same number of protons and a different number of neutrons are called isotopes. An ion is a species in which the number of electrons is not equal to the number of protons. An anion has more electrons than protons (a net negative charge) and a cation has fewer electrons than protons (a net positive charge), all of which has been previously taught in middle school.

All reactions are reversible to a degree, and many reactions do not proceed completely toward products. This does not mean that the reaction has stopped, but rather that the rate of the reverse reaction is equal to the rate of the forward reaction. Although some reactions appear to proceed only in one direction, the reverse reaction can occur; however, the occurrence of the reverse reaction is highly unlikely (e.g., combustion reactions).

Reactions occur when reacting particles collide in an appropriate orientation and with sufficient energy. Hence, all stable species require the input of energy to initiate a reaction. The amount of energy required to initiate a reaction is called the activation energy. When the concentration, or pressures, of reactants are increased the probability of a molecular collision increases thereby increasing the reaction rate. When molecules/atoms collide with increased energy, as is often – but not always - indicated with a rise in temperature, they are more likely to react. That said, most reactions occur in solution or in the gas state because the reacting particles are free to move and can collide and interact with each other. Reactions among solids are not as prevalent because a reaction can only occur at the surface of a solid.

Reactions can be classified to better understand how specific chemical reactions proceed. Some general types of chemical reactions are synthesis reactions, decomposition reactions, single-replacement and double replacement reactions, and combustion reactions.

The rate of reaction can be defined as the change in the amount of products or reactants per unit of time. The rates at which reactions occur are affected by factors such as the addition of a catalyst, temperature, and as was previously stated, concentration and pressure. The addition of a catalyst lowers the activation energy, thereby causing more molecules to overcome the activation energy and thus leading to an increased rate of reaction. Enzymes are catalysts that enable important biological processes to occur.

Reactions that appear to proceed only in one direction usually release a large amount of energy. An input of energy is required to make such a reaction go in the reverse direction. If a chemical system at equilibrium is disturbed by a change in the conditions of the system, 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, resulting in a possibly unfavorable reaction.

Reactions can occur between acids and bases, which can contain covalent bonds, and result in the production of an ionic species (Hydrogen ions, Hydroxide ions). Acids are proton donors and are capable of donating protons to base particles or proton acceptors, i.e., proton transfer reaction. Thus, the acidity of an aqueous solution is often expressed as pH, where pH is related to the concentration of the hydronium ion (H$_3$O$^+$). Detailed instruction about solutions and factors that affect solubility may be included in an advanced course.

- **Stoichiometry**

A stoichiometric calculation is a conversion from one amount of substance in any chemical change to another amount and can be made as long as the relationships among all of the reactants and all of the products at the molecular level are known. The quantitative relationship between reactants and products is determined at the atomic-molecular level. The quantities can be in terms of mass, mole, volume of gas, or volume of solutions. Molarity is the amount of a substance in solution and is the
standard unit of concentration in mole per liter. Specific calculations can be made to determine various types of information about a sample of matter: the amount of particles in a substance as determined from its mass, percent composition of a compound, empirical formulas, and molecular formulas. Molality and Normality are concepts reserved for more advance study.

- Conservation

Central to the principle of the conservation of matter is maintaining the same number of atoms. Whenever a change occurs, the total number of atoms within a closed system remains the same; therefore, the total mass of the system remains the same. Central to the principle of the conservation of energy is the retention of energy within a closed system through the completion of a reaction process.

Mass-energy is always conserved for all defined systems, for all types of interactions, and at all scales; although matter and energy can be transferred in or out of a system. By defining a system, any changes that occur can be tracked. Energy changes are measured by the changes that occur to the system, as is often indicated by temperature changes. For example, an exothermic process is identified when the temperature of that which surrounds a system is increased. The system is said to lose energy; the energy moves from the system to its surroundings. If the temperature of a system increases absorbing energy or heat from its surroundings with a higher original temperature, then the system is said to be endothermic. Accordingly, these temperature changes are the effects of changes in the thermal energy of a system; and it is the thermal energy that is associated with the translational, rotational, and vibrational movement of particles in a system.

When a substance changes state, the relative arrangement of the particles rearrange, as well as the distance between these particles. The atoms, however, that make up the particles of the substance are not rearranged to form a new substance. When thermal energy is added to a solid, liquid or gas, most substances increase in volume because the particles have increased kinetic energy, causing a greater distance between the particles. The distance between particles, in most substances, increases as they change from solid to liquid to gas, meaning that the density of solid is usually greater than the density of a liquid. The density of a liquid is always greater than the density of a gas.

Entropy, a measure of the number of possible arrangements of atoms, molecules or energy in a system, is the relative possibility of disordered arrangements of particles in a system. In parallel, at the atomic-molecular level, the movement of the particles within a system is associated with the kinetic energy of its particles and subsequently determines the state of matter from which the material is composed. In a solid, the kinetic energy of the particles making up the substance is not great enough to overcome the attractions holding them together. Although the particles vibrate in place, the distance between them does not increase. In a liquid, the kinetic energy of the particles making up the substance is sufficient to overcome the attractions, thereby allowing the particles to move relative to each other. Most of the particles, however, do not have enough kinetic energy to completely overcome the attractions between them and enter the gas phase. In a gas, the particles have enough kinetic energy to overcome any attractions. Generally, the separation between gas particles is such that their interactions are minimal. For each state, the temperature needed for a change of state to occur depends on the amount of energy that is required to overcome the attractions between the particles.

- Gas Laws

The kinetic-molecular theory is an explanation of the macroscopic properties of gases, using the idea of particle interactions and motions. This theory postulates, gas consists of very small particles that have mass; the distances separating gas particles are large; the particles are in constant, rapid, random motion; collisions of gas particles with each other, or the wall of the container are elastic; the average kinetic energy of the gas particles depends only on the temperature of the gas; gas particles exert no force on one another – the attractive forces between gas particles are very weak. Standard Temperature and Pressure (STP) is the condition under which various properties of gases are normally measured and reported in order to make the discussion of the comparable behavior of gas convenient. When the temperature remains constant the pressure and volume of a sample of gas are inversely proportional to each other. If the pressure remains constant, the volume of a fixed amount of gas is directly proportional to its absolute temperature. Absolute temperature is based on a scale that has its minimum temperature at absolute zero – theoretically, the lowest possible temperature that can be reached. In combination with the idea that equal volumes of gases at the same temperature and pressure contain an equal number of particles (Avogadro's Law), the physical behavior of an ideal gas is represented by an equation ($PV=nRT$) where $R$ is the ideal gas constant (represented in multiple formats, 8.31 Joules/ (mole x K) is one example).
Nuclear Reactions

Nuclear reactions involve only changes in the nucleus. Neutrons have little effect on how an atom interacts with other atoms, yet the number of neutrons does affect the mass and stability of the nucleus. Atoms with the same number of protons and a different number of neutrons are called isotopes. Atoms with an unstable nucleus are called radioisotopes. When an atom has an unstable nucleus, the unstable nucleus emits radiation (e.g., alpha, beta, gamma and positron). This process, called radioactive decay, increases the stability of the nucleus. Balance nuclear reactions serve as a representation of how this process proceeds while observing conservation.

Half-life, as previously learned in middle school, is a measure of the rate of radioactive decay, or the amount of time it takes for half of a radioactive sample initially present to decay to its products. For any radioisotope, the half-life is constant and unique and can be used to determine the age of the material. There are innumerable implications regarding radioisotopes and the benefits, or dangers, they provide (e.g., tracers of biological processes, ability to treat cancer cells, energy sources, etc.).

When a nuclear reaction occurs, the mass-energy inter-conversion is significant. The nuclear reactions, such as fission and fusion, are accompanied by large energy changes that are much greater than those that accompany chemical reactions. Fission, the splitting of a nucleus into small fragments, and fusion, the combining of two nuclei, are types of nuclear reactions. These nuclear reactions can be used as a controlled source of energy.

All of the elements, except hydrogen and helium, originated from the nuclear fusion reactions of stars. This production of heavier elements from lighter elements by stellar fusion has never ceased and continues today.

### Expectations for Learning: Cognitive Demands

This section provides definitions for Ohio’s science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science.

### Expectations for Learning: Visions into Practice

This section provides examples of tasks that students may perform; this includes guidance for developing classroom performance tasks and assessments. It is not an all inclusive checklist of what should be done, but is a springboard for generating innovative ideas.

### Instructional Strategies and Resources

These are strategies for actively engaging students with the topic and for providing hands-on minds-on observation and exploration of the topic, including authentic data resources for scientific inquiry, experimentation and problem-based tasks that incorporate technology and technological and engineering design. Resources selected are printed or web-based materials that directly relate to the particular Content Statement. It is not intended to be a prescriptive list of lessons.

**Indicators in Chemistry** is a video that shows how the content of acids and bases can be integrated into a technological design activity.

**Masterminding Molecules** seeks to develop logic and reinforce the principles of fair-testing. It introduces the importance of concepts such as size, polarity and drug-like properties in the discovery of new medicines.

**The Design Studio** introduces the concepts of shape, enzyme inhibition, potency, drug-like properties and the need to achieve a balance of properties to discover effective medicines.
Oil strike is an interactive, chemistry themed game. Try and maximize your profits as you build your own refineries.

Common Misconceptions
Chemists do not agree on how the “mole” should be defined: three meanings are that a mole is an individual unit of mass, a mole is a portion of substance and a mole is a number. Suggested (Kind, 2004) is that students be shown elements in a whole-number mass ratio…show that the ratio remains fixed regardless of the number of atoms…introduce the masses in grams, then introduce Avogadro’s number while reinforcing atom size.

Compounds with ionic bonds behave as simple molecules…instead explore students’ understanding of simple events like, water boiling and sodium chloride and sugar dissolving, ice melting. Make the events explicit by carrying them out in the students’ presence and using molecular models to probe thinking about which bonds break and form (Kind, 2004).

The first element in a formula is responsible for bond formation…instead use cognitive conflict to show why elements form different types of bonds and that atoms form compounds in the most energetically favorable way (Kind, 2004).

Atoms “want” to form bonds…instead use electrostatics to explain bond formation (Kind, 2004). There are only two types of bonds – covalent and ionic…instead be consistent in using bonding terminology like “induced dipole-dipole bonds” and “permanent dipole-permanent dipole bonds because it is much more descriptive and clearly explains the kind of interaction involved (Kind, 2004).

Acids can burn and eat material away (Kind, 2004)...introduce acids and bases alongside each other. Neutralization means an acid breaking down (Kind, 2004)...show the difference between “strong” and “weak” and dilute and concentrated.

A base/alkali inhibits the burning properties of an acid (Kind, 2004)...introduce “neutralization” as a reaction involving an acid and a base reacting together.

Diverse Learners

Classroom Portals
Energetics and Dynamics emphasizes the importance of learning about energetics and dynamics in order to improve students’ understanding of basic principles of chemistry.

Back to the INDEX
Environmental Science: Syllabus and Model Curriculum

Course Description:

Environmental Science is a high school level course which satisfies Ohio Core science graduation requirements as required by section 3313.603 of the Ohio Revised Code that requires a course with 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.

Students engage in investigations 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.

Science Inquiry and Application

*During the years of grades 9 through 12 all students must use the following 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;
- Use technology and mathematics to improve investigations and communications;
- Formulate and revise explanations and models using logic and evidence (critical thinking);
- Recognize and analyze explanations and models; and
- Communicate and support a scientific argument.

Course Content

**Earth Systems: Interconnected Spheres of Earth**

**Biosphere**
- Evolution and adaptation in populations
- Biodiversity
- Ecosystems (equilibrium, species interactions, stability)
- Population dynamics

**Atmosphere**
- Atmospheric properties and currents

**Lithosphere**
- Geologic events and processes

**Hydrosphere**
- Oceanic currents and patterns (as they relate to climate)
- Surface and ground water flow patterns and movement
- Cryosphere

*Movement of matter and energy through the hydrosphere, lithosphere, atmosphere, and biosphere*
- Energy transformations on global, regional, and local scales
- Biogeochemical cycles
- Ecosystems
- Climate and weather
**Content Elaboration:** 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.

The focus for this topic is on the connections and interactions between Earth’s spheres (the hydrosphere, atmosphere, biosphere and lithosphere). Both natural and human-made interactions must be 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 (such as a volcanic eruption 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 must be researched and investigated using actual data. The emphasis is on the interconnectedness of Earth’s spheres and the understanding of the complex relationships between each, 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 between Earth’s spheres.

**Expectations for Learning: Cognitive Demands**

*This section provides definitions for Ohio’s science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science.*

**Expectations for Learning: Visions into Practice**

<table>
<thead>
<tr>
<th>Choose a specific location in the United States, research and analyze the patterns of climate change throughout the geologic record, historic data (human records) and present-day data for the location. Be able to explain the interpretation and analysis of the data. Create a graphical representation of the pattern and discuss with the class.</th>
</tr>
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<tbody>
<tr>
<td>Research or investigate an actual environmental/geologic event (such as a specific release of a toxin/contaminant, hurricane, earthquake, flood, fire, or landslide) and determine how each of Earth’s spheres was impacted. Long-term and short-term impacts must be included. Must provide scientific evidence and data to support conclusions and trace movement of contamination or energy through each sphere. Use a multimedia presentation to share findings with the class.</td>
</tr>
<tr>
<td>Research an actual contamination event (that has quantitative data available). Use a computer-modeling program (many are available through freeware sites, fate and transport modeling) to model and predict the movement of the contamination through Earth’s spheres. Develop and evaluate solutions for the cleanup, containment, or reduction of the contamination. Include consequences and/or alternatives for the proposed solution. Present the findings to the class or an authentic audience.</td>
</tr>
<tr>
<td>Plan and implement an experiment or demonstration to illustrate the factors that lead to changing oceanic currents (both deep and shallow), can be 3-D or virtual. Document all steps and prepare a presentation or a poster session for the class (be able to defend the process and the results).</td>
</tr>
<tr>
<td>Plan and implement an investigation to explore biomagnification or bioaccumulation within a specific Ohio ecosystem (existing public case studies can be used, such as a local Brownfields case-see resource listed below). Document the steps and process to collect or research, evaluate or test, and analyze the data. Research should include the possible impact to humans. Present the process and results to the class verbally or in writing.</td>
</tr>
</tbody>
</table>
Choose a specific living species. Using scientific data trace the history of that species; show existing, proven evolutionary relationships, environmental (both biotic and abiotic) requirements, global locations, ecosystem characteristics, and sustainability predictions. Must use quantifiable data to support findings. Present finding to the class orally, through demonstration/explanation, or a poster session.

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.

Research or conduct a field investigation for a specific invasive species that is present in the local community or in Ohio. Examples of research questions: how did the organism get into Ohio, what is being done to control the spread of the species, what is the impact of the species on the native population? Must use quantifiable data to draw conclusions. Present the research results in writing or orally.

Investigate and research the effect that climate change is having, or has had on a specific species (can be living or extinct), such as the harp seal or elk horn coral, or an ecosystem, such as the Great Barrier Reef or the Arctic Circle. Research and analyze quantifiable scientific data pertaining to food availability, reproductive requirements and changes, adaptations, or population changes to draw conclusions. Present data and conclusions to the class.

**Instructional Strategies and Resources**

- [http://climatechange.umaine.edu/Research/projects/byrdglacier.html](http://climatechange.umaine.edu/Research/projects/byrdglacier.html)  This site provides a scientific case study of a specific glacier, including quantifiable data that documents measurable changes each year.

- [http://bprc.osu.edu/](http://bprc.osu.edu/)  This is the link to the OSU Byrd Polar Research site. There are numerous educational resources that are related to glacial geology and climate change.

- [http://www.epa.state.oh.us/derr/SABR/brown_dt/browndtb.aspx](http://www.epa.state.oh.us/derr/SABR/brown_dt/browndtb.aspx)  This link provides a map of all regional Brownfields projects. This can be a resource to provide data and documentation for local case studies involving a variety of hazardous releases into the environment and quantifiable data and monitoring data may be available.

- [http://www.ngwa.org/](http://www.ngwa.org/)  The National Ground Water Association offers information, data, and resources to support teachers in teaching all aspects of ground water.

- [http://www.ncwater.org/Education_and_Technical_Assistance/Ground_Water/Hydrogeology/](http://www.ncwater.org/Education_and_Technical_Assistance/Ground_Water/Hydrogeology/)  This is a link that provides some basic hydrology background, including ways to calculate ground water velocity and outlining different types of aquifers to help in teaching about ground water studies.

- [http://www.intellicast.com/National/Wind/JetStream.aspx](http://www.intellicast.com/National/Wind/JetStream.aspx)  This website provides real-time data for the jet stream (updated daily), this includes velocities and patterns on an isometric map.


- [http://www.diese.org/library/query.do?q=&s=0&gr=02](http://www.diese.org/library/query.do?q=&s=0&gr=02)  The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies, and other scientific agencies. Grade 9-12 resources provided at this link.

- [http://www.noaa.gov/sciencemissions/bp0ispill.html](http://www.noaa.gov/sciencemissions/bp0ispill.html)  NOAA provides real-time data for many of their projects and research missions. This includes real-time ocean current data collected from free floating buoys.

- [http://www.dnr.state.oh.us/tabid/3501/Default.aspx](http://www.dnr.state.oh.us/tabid/3501/Default.aspx)  Project Wet offers training and resources for K-12 teachers. Promoting deep understanding about all aspects of water and the interconnectedness of all of Earth's spheres (Earth Systems). Training and workshop opportunities can be found at this link.

- [http://www.projectwet.org/water-resources-education/water-quality-education/](http://www.projectwet.org/water-resources-education/water-quality-education/)  Healthy Water, Healthy People is a Water Quality Educators Guide that offers ideas and resources for teaching all aspects of water and water
contamination issues. Ideas for field monitoring and research projects, as well as investigative students are found within the program. Teacher training is also part of the program.

http://www.agiweb.org/earthcomm/ EarthComm is a program that utilizes many different strategies to reach students of all learning levels. The teaching of environmental science through relating the classroom to the real world is essential for many learners.

http://www.nationalacademies.org/education/tsresources.html The National Academy of Science provides a number of resources related to climate change and greenhouse gases. Some of the options include web quests, virtual/digital learning, virtual fieldtrips, and field research ideas. By providing alternate options and choices that can be completed by students at different paces, all students can benefit.

Common Misconceptions

http://www.nsta.org/about/positions/evolution.aspx This NSTA Position Paper is helpful in addressing concerns and misconceptions from students regarding evolution.
http://www.wheaton.edu/Biology/faculty/fvd/Teachingethical.pdf Students may have difficulty separating science from non-science factors as they relate to the different parts of the environment. It is important to distinguish “what is science” and therefore, what will be included in an Environmental Science class, especially as it relates to climate change and evolution. Identifying and understanding personal bias and ethical issues are an important step in recognizing science.

http://www.epa.gov/teachers/climate.html The EPA provides support for teachers that are teaching about climate change. To address student misconceptions regarding this issue, it is important to use real-time data and research, which can be found through the EPA.

http://serc.carleton.edu/introgeo/gallerywalk/misconceptions.html Misconceptions regarding all aspects of environmental science must be addressed through scientific data analysis, investigation, and research. Discussing the conclusions and findings through a professional “gallery walk” can be a very useful way to determine possible misconceptions that exist for the class and address them.

Diverse Learners

Classroom Portals

http://www.learner.org/resources/series209.html This website shows teaching (in a high school level environmental science class) environmental science using a systems approach (integrated Earth systems).

Course Content

Earth's Resources

- Energy resources
  - Renewable and nonrenewable energy sources and efficiency
  - Alternate energy sources and efficiency
  - Resource availability
  - Mining and resource extraction
- Air and air pollution
  - Primary and secondary contaminants
  - Greenhouse gases
  - Clean Air Act
- Water and water pollution
  - Potable water and water quality
  - Hypoxia, eutrophication
  - Clean Water Act
  - Point source and non-point source contamination
- Soil and Land
Content Elaboration: 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 upon grades 6-8 within the Earth and Space Science strand (sections pertaining to energy and Earth’s resources) and the Biology and Physical Science (in particular chemistry and energy topics) courses at the high school level.

To understand the effects that certain contaminants may have on the environment, scientific investigations and research must be conducted on a local, national and global level. Water, air, land, and biotic field and lab sampling/testing equipment and methods must be utilized with real-world application. Quantifiable field and/or lab data must be 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 (such as 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. For example: wetland loss or mitigation, surface or ground water contamination (including sediment, chemical, or thermal contamination), acid rain, septic system or sewage overflows/failures, landfill seepage, underground storage tank/pipe releases, deforestation, invasive species, air pollution (such as 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 within both 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 must be evaluated as it pertains to both the environmental and human risk. 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 laws and regulations that exist to preserve 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 an important part of this topic.

Expectations for Learning: Cognitive Demands
This section provides definitions for Ohio’s science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science.

### Expectations for Learning: Visions into Practice

<table>
<thead>
<tr>
<th>Expectations for Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choose a specific environmental problem, such as the effect of herbicides in water (for example; Atrazine), an invasive species (such as purple loosestrife or the Asian carp), or carbon monoxide in the atmosphere, and research the history, the scientific data before and after relevant laws were passed, and how this problem is being addressed in other countries/globally. Computer models or programs can be used to predict/analyze the problem or the movement of the contamination. Present scientific evidence and quantifiable data orally, through a poster session, or in written form (scientific research paper).</td>
</tr>
<tr>
<td>Design and conduct a field investigation that concentrates on a specific environmental problem (such as sediment contamination or acid mine drainage) and how the problem can be remediated. Compare results to similar communities, recommended limits, permit requirements, or other published results. Analyze the data and make specific recommendations to limit, remediate, reduce or prevent the problem. Present findings to an authentic audience from the community.</td>
</tr>
<tr>
<td>Research and document land-use planning or management in the community or at a specific location. Attend community meetings pertaining to land-use, land management, or zoning plans. What factors are used in determining use? What data is collected and analyzed? What changes are on the horizon? Discuss in class.</td>
</tr>
<tr>
<td>Take a field trip to visit the water treatment facility or watch the drilling of water well. Document observations, including information about how water is treated prior to and after use, specific issues that may impact the source, the location of the original water source, specific tests conducted (materials and methods needed to test and how the tests are conducted, results of the tests), the steps taken to monitor the water at the source and throughout the process (including from the facility/well into the residence). Discuss with the class.</td>
</tr>
<tr>
<td>Using real-time data, research the most severe environmental problems (and the root causes for the problem) 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).</td>
</tr>
<tr>
<td>Research and collect specific data for a mass wasting or desertification event (can be present day or historical). Research questions should include: what factors lead to the event, what was the result of the event (how was each of Earth’s spheres impacted?), what data is present (analyze the data and draw conclusions), what laws are related to the event, how can this be prevented in the future. Record the results graphically or in a scientific report.</td>
</tr>
</tbody>
</table>

### Instructional Strategies and Resources

- **http://www.ngwa.org/** The National Ground Water Association offers information, data, and resources to support teachers in teaching all aspects of ground water.

- **http://oh.water.usgs.gov/projects.htm?Category=Surface+Water** This page of the USGS website outlines current surface water projects within the state of Ohio. Surface water quality data (including stream gauge and volume data) can be found and used to support local field investigations. There are also links to provide historic surface and ground water data for analysis.

- **http://rais.ornl.gov/** This is a link to the risk assessment information system, within the federal EPA. There are specific Ohio risk assessments that can be used to provide background data or specific case studies. This helps to illustrate the types of tests that are included in a risk assessment and also provides different risk levels for specific contaminants.

- **http://www.epa.gov/scram001/aqmindex.htm** This is a link to the US EPA website that houses a SCREEN3 computer modeling program for air pollutants. There are also resources and data explaining the use of computer modeling and air pollution that may be helpful in student research and investigation projects.

- **http://www.ohiodnr.com/mineral/acid/tabid/10421/Default.aspx** This page of the ODNR website discusses acid mine
drainage issue in Ohio. There are also specific links to Ohio watersheds (including maps of the watershed locations) that are in the abatement program and water quality data to study changes within a local area.

http://www.epa.state.oh.us/portals/47/facts/ohio_wetlands.pdf This is a link to a discussion about Ohio wetlands and the delineation, qualitative analysis of Ohio wetlands.

http://www.oardc.ohio-state.edu/ferel/riparian_home.htm The National Park Service provides information about Ohio woodlands and the types of data required to determine woodland quality. This particular link addresses riparian woodlands.

http://www.epa.state.oh.us/Rules_and_Laws.aspx This site outlines Federal and State Environmental Laws.

http://www.diese.org/library/query.do?q=&s=0&gr=02 The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies, and other scientific agencies. Grade 9-12 resources provided at this link.

http://www.swaco.org/SmartKids/Resources.aspx This is a link to the resource section of the Solid Waste Authority of Central Ohio (SWACO). Ideas about landfill tours, additional information about waste management, and specific problems facing Ohio can be found through these resources.

http://www.scienecnos.org/ http://www.sciencedaily.com/ Each of these links can be used for class discussions and highlighting current event/science in the news. The information is updated weekly or bi-weekly and provides references and resource sites for more in-depth discussion.

http://www.noaa.gov/sciencemissions/bpoilspill.html NOAA provides real-time data for many of their projects and research missions.

http://www.epa.state.oh.us/oeof/ee_resources.aspx This is an index page for numerous environmental educational resources available through the Ohio EPA and associated agencies.

http://geology.com/ This website is a connection to current events in all topic areas of geology. This includes resources and uses of resources. There are a number of resource links within the document that can help support this topic.

http://ohiodnr.com/tabid/18951/Default.aspx This link provides data regarding sustainable water programs that are conducted in Ohio (monitoring programs, water quality testing information, and contact information for the ODNR scientists that work in these areas).

http://learningcenter.nsta.org/product_detail.aspx?id=10.2505/5/SG-27 NSTA provides learning modules called “Sci Packs” that are designed to increase teacher content knowledge through inquiry-based modules. This module addresses the Earth’s Resources and humans.

http://www.dnr.state.oh.us/tabid/3501/Default.aspx Project Wet offers training and resources for K-12 teachers. Promoting deep understanding about all aspects of water and the interconnectedness of all of Earth’s spheres (Earth Systems). Training and workshop opportunities can be found at this link.

http://professionals.collegeboard.com/profdownload/cbcs-science-standards-2009.pdf The college board provides enduring understandings recommended for AP Environmental Science which can help to form discussion questions and research for this topic. Appendix A (page 175) of this document contains the Environmental Science information.

http://www.projectwet.org/water-resources-education/water-quality-education/ Healthy Water, Healthy People is a Water Quality Educators Guide that offers ideas and resources for teaching all aspects of water and water contamination issues. Ideas for field monitoring and research projects, as well as investigative students are found within the program. Teacher training is also part of the program.

Common Misconceptions
This website lists common high school student misconceptions that deal with renewable energy efficiency. Suggestions are offered to overcome the misconception through exploration and investigation.

Misconceptions regarding all aspects of environmental science must be addressed through scientific data analysis, investigation, and research. Discussing the conclusions and findings through a professional “gallery walk” can be a very useful way to determine possible misconceptions that exist for the class and address them.

### Diverse Learners

### Classroom Portals

This website shows teaching (in a high school level environmental science class) environmental science using a systems approach (integrated Earth systems).

### Course Content

#### Global Environmental Problems and Issues

- Human population
- Potable water quality, use, and availability
- Climate change
- Sustainability
- Species depletion and extinction
- Air quality
- Food production and availability
- Deforestation and loss of biodiversity
- Waste management (solid and hazardous)

**Content Elaboration:** 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 real world must be 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. For example: building water or air filtration models, investigating climate change data, endangered or invasive species monitoring, studying the environmental effects of increasing human population are all global topics that can be explored. Researching contemporary discoveries, new technology, new discoveries can lead to improvement in environmental management.

**Expectations for Learning:**

**Cognitive Demands**

This section provides definitions for Ohio’s science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science.

**Expectations for Learning:**

Visions into Practice

Investigate and research global human population patterns and changes over time. Example research questions include: what countries have marked changes in populations at present, in the past? What are the factors that affect population change, what are verifiable relationships related to population (such as; economic indicators, education levels, laws, resource availability, environmental conditions). Provide evidence and data to support conclusions. Document the research in a scientific research paper.

Investigate and/or research (using quantifiable data and evidence) the relationship between deforestation and changing weather or in some cases climate at a specific location (like the Amazon Region of South America). Analyze
the data and draw a conclusion based upon the analysis. Discuss the conclusion with the class.

Plan and implement an investigation to determine the water quality of a section of a local stream. This includes researching and conducting standard water quality tests and how to analyze the results. Compare the results to known data from a different country (with a similar setting). Compare and contrast the data and analyze the results (research questions can include: reasons for any statistically significant differences? Compare the topography or geomorphology of the location, testing methods, materials and/or equipment used, testing dates/times/locations, existing, applicable, environmental laws or requirements). Document all results and present to an authentic audience.

Develop a risk assessment for a specific company. Research one particular toxin or hazardous chemical used by the company (such as diesel fuel) to determine possible risks and pathways to the environment and humans. The assessment should include: nature of the toxin/chemical (for example is the material flammable, does it react when wet?), on-site use and handling (including existing safety practices) of the chemical/toxin, by-products (such as vapors or dilution processes), storage, transportation of the chemical/toxin, required documentation, emergency plans/guidelines, topography and geology of the area. Use a computer-modeling program (many are available through freeware sites) to model and predict the movement of the possible pathways of the toxin/chemical and recommendations of methods to contain the release of the toxin/chemical. Present the findings to the class or an authentic audience.

**Instructional Strategies and Resources**

http://ohiodnr.com/tabid/18951/Default.aspx This link provides data regarding sustainable water programs that are conducted in Ohio (monitoring programs, water quality testing information, and contact information for the ODNR scientists that work in these areas).

http://rais.ornl.gov/ This is a link to the risk assessment information system, within the federal EPA. There are specific Ohio risk assessments that can be used to provide background data or specific case studies. This helps to illustrate the types of tests that are included in a risk assessment and also provides different risk levels for specific contaminants.

http://www.epa.ohio.gov/portals/30/rules/RR-031.pdf This OEPA site provides guidance for a full risk assessment, including all types of monitoring and data requirements. This can be used to provide an authentic learning experience for students as parts of the requirements can be modified and simplified for high school students. It contains examples of the level of detail required to determine human risk and site evaluation (which again, should be modified for high school students).

http://www.epa.gov/risk/ This is the federal EPA risk assessment site that has helpful information regarding what is involved in conducting a risk assessment.

http://ceenve3.civeng.calpoly.edu/cota/env436/fate.html This site provides information about the use of fate and transport modeling in tracing the movement of hazardous materials/contamination. It also provides links to educational fate and transport programs that are available; some are “freeware” that may assist in demonstrations or small student investigations.

http://water.usgs.gov/software/lists/general/ This USGS page provides a list of free software downloads that are available through USGS that apply directly to modeling of surface and/or groundwater.

http://www.scien cnens.org/ http://www.s cience daily.com/ Each of these links can be used for class discussions and highlighting current event/science in the news. The information is updated weekly or bi-weekly and provides references and resource sites for more in-depth discussion.

http://www.noaa.gov/sciencemissions/bp oilspill.html NOAA provides real-time data for many of their projects and research missions. These relate to water and climate change.

http://professionals.collegeboard.com/profdownload/cb scs-science-standards-2009.pdf The college board provides enduring understandings recommended for AP Environmental Science which can help to form discussion questions and research for this topic. Appendix A (page 175) of this document contains the Environmental Science information.
Project Wet offers training and resources for K-12 teachers. Promoting deep understanding about all aspects of water and the interconnectedness of all of Earth’s spheres (Earth Systems). Training and workshop opportunities can be found at this link.

Healthy Water, Healthy People is a Water Quality Educators Guide that offers ideas and resources for teaching all aspects of water and water contamination issues. Ideas for field monitoring and research projects, as well as investigative students are found within the program. Teacher training is also part of the program.

**Common Misconceptions**

Students may have misinformation and misconceptions that pertain to climate change. To address this, it is important to provide evidence of climate change throughout Earth’s history and current data to document temperature changes (surface and oceanic). Data and other resources to help with teaching climate change can be found at the EPA website listed above.

Misconceptions regarding all aspects of environmental science must be addressed through scientific data analysis, investigation, and research. Discussing the conclusions and findings through a professional “gallery walk” can be a very useful way to determine possible misconceptions that exist for the class and address them.

**Diverse Learners**

This website shows teaching (in a high school level environmental science class) environmental science using a systems approach (integrated Earth systems).

**Classroom Portals**

This website shows teaching (in a high school level environmental science class) environmental science using a systems approach (integrated Earth systems).
### Physical Geology: Syllabus and Model Curriculum

#### Course Description:
Physical Geology is a high school level course which satisfies Ohio Core science graduation requirements as required by section 3313.603 of the Ohio Revised Code that requires a three-unit course with 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.

Students engage in investigations 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.

#### Science Inquiry and Application

*During the years of grades 9 through 12 all students must use the following 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;
- Use technology and mathematics to improve investigations and communications;
- Formulate and revise explanations and models using logic and evidence (critical thinking);
- Recognize and analyze explanations and models; and
- Communicate and support a scientific argument.

#### Course Content

**Minerals**
- Atoms and Elements
- Chemical bonding (ionic, covalent, metallic)
- Crystallinity (crystal structure)
- Criteria of a mineral (crystalline solid, occurs in nature, inorganic, defined chemical composition)
- Properties of minerals (hardness, luster, cleavage, streak, crystal shape, fluorescence, flammability, density/specific gravity, malleability)

**Content Elaboration:**
This unit builds upon the middle school Earth science strand, where common minerals are tested, minerals are defined, and minerals are classified. The emphasis of this topic is to relate the chemical and physical components of minerals to the properties of the minerals. This requires extensive mineral testing and observation and the use of models. Properties such as cleavage and hardness should be 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: Cognitive Demands**

This section provides definitions for Ohio’s science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science.

**Expectations for Learning: Visions into Practice**

- Use crystal or atomic models to illustrate the crystal structure of common minerals. Relate the structure of the model to a specific quantifiable property (such as cleavage or hardness). Demonstrate and explain results to the class.
- Demonstrate (through specific testing, data collection, analysis, and research) the relationship between mineral use, chemical formula, chemical bonds, and the properties of the mineral. Document findings in writing.
- Research a specific mineral. Research questions should include: the locations where the mineral can be found (globally), the environmental conditions that must exist; the length of time is takes to form crystals, how the mineral is
extracted, uses of the mineral, hazards, precautions, safety issues pertaining to the mineral or the extraction of the mineral, economic value of the mineral, and any laws that may pertain to the mineral or the extraction of the mineral. Document the data in a scientific research paper or a poster session.

Design and conduct an experiment to test specific properties of a mineral that has a unique use (such as a quartz battery or gypsum wallboard). Document process and findings in a scientific lab report.

### Instructional Strategies and Resources

- [http://geology.com/](http://geology.com/)  This website is a great connection to current events in all topic areas of geology. This includes minerals and mineral uses. There are a number of resource links within the document that can help support this topic.

- [http://minerals.usgs.gov/minerals/](http://minerals.usgs.gov/minerals/) The USGS provides mineral resources and information that can support the teaching of minerals at the high school and college level.

- [http://www.minsocam.org/](http://www.minsocam.org/) The Mineralogical Society of America offers training, workshops, data, and resources to support learning about minerals and geology.

- [http://www.dlese.org/library/query.do?q=&s=0&gr=02](http://www.dlese.org/library/query.do?q=&s=0&gr=02) The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies, and other scientific agencies. Grade 9-12 resources provided at this link.


### Common Misconceptions

- [http://serc.carleton.edu/NAGTWorkshops/intro/misconception_list.html](http://serc.carleton.edu/NAGTWorkshops/intro/misconception_list.html) This website lists a number of geologic misconceptions for students within the high school and college age group.

- [http://www-istp.gsfc.nasa.gov/istp/outreach/sunearthmiscons.html](http://www-istp.gsfc.nasa.gov/istp/outreach/sunearthmiscons.html) This website lists common misconceptions for all ages about the Earth and geology.

- [http://serc.carleton.edu/introgeo/gallerywalk/misconceptions.html](http://serc.carleton.edu/introgeo/gallerywalk/misconceptions.html) Misconceptions regarding all aspects of geology must be addressed through scientific data analysis, investigation, and research. Discussing the conclusions and findings through a professional "gallery walk" can be a very useful way to determine possible misconceptions that exist for the class and address them.

### Diverse Learners

### Classroom Portals

- [http://www.learner.org/resources/series209.html](http://www.learner.org/resources/series209.html) This website shows teaching (in a high school level environmental science class) science using an Earth Systems Science approach.

### Course Content

#### Igneous, Metamorphic, and Sedimentary Rocks

**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)

**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)

**Sedimentary**
The 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

Division of sedimentary rocks and minerals (chemical, clastic/physical, organic)
Depositional environments
Streams (channels, streambeds, floodplains, cross-bedding, alluvial fans, deltas)
Transgressing and regressing sea levels

**Content Elaboration:** Geologic, topographic, seismic, and aerial maps should be used to locate and recognize igneous, metamorphic, and sedimentary structures and features. Advancements in technology allow 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. Also included in this topic are the processes and environment that lead to fossil fuel formation (note: this links to the energy resources section below). Bowen's Reaction Series should be used to develop an understanding of the relationship of cooling temperature, formation of specific igneous minerals, and the resulting igneous environment. The magnetic properties of Earth should be evaluated through the study of the available evidence. While the ocean is included within the sedimentary topic, it can be incorporated into other topics also. Features found in the ocean can include all types of environments (igneous, metamorphic, or sedimentary). New technological advances can be used to illustrate 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 the Earth.

**Expectations for Learning:**

**Cognitive Demands**
This section provides definitions for Ohio's science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science.

**Expectations for Learning: Visions into Practice**

Use a geologic cross-section (or conduct a field investigation) for a specific location to analyze interpret the geologic history (rock type, formation, fossils or minerals present) and environmental conditions (including volcanic activity and/or transgressing and regresssing sea levels). Share findings (can be a model, presentation, or graphically) with the class.

Identify specific geologic features using LANDSAT or other remote sensing data. Identify the factors required to create the specific features. Document findings graphically and in writing in a scientific journal or portfolio (can use an "e-portfolio").

Create a map, model, or lab investigation to illustrate a specific ocean current using real-time data. Relate the oceanic current to the Coriolis effect, density changes, and physical features that exist. Present or demonstrate the product to the class (be prepared to defend and explain process and result).

Design an investigation or experiment to demonstrate the magnetic reversals and the resulting magnetic striping that occurs at oceanic ridges. Document the process and result in writing (can also discuss or present to the class).

Create a topographic, soil or geologic map of the school or community using actual data collected from the field. Can use GPS/GIS readings, field studies/investigation, aerial maps, or other available data to generate the map. Present final map in a poster session, with data used in the development of the map and the analysis of the data.

Design and conduct a field study in a local area to locate fossil evidence that can help to interpret the geologic history of the area (when combined with other rock evidence). Document the field work and steps of the investigation in a scientific journal. Share the analysis of the data and the interpretation of the geologic history with the class through a presentation, portfolio (or “e-portfolio”), or poster session.

**Instructional Strategies and Resources**
http://www.dlese.org/library/query.do?q=&s=0&gr=02 The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies, and other scientific agencies. Grade 9-12 resources provided at this link.
Project Wet offers training and resources for K-12 teachers. Promoting deep understanding about all aspects of water and the interconnectedness of all of Earth’s spheres (Earth Systems). Training and workshop opportunities can be found at this link.

The college board provides Earth Science recommendations for Earth Science grades 6-12 (beginning on page 21). Essential questions and scientific applications are included in this document to encourage investigation and scientific inquiry. In addition, connections to other topics and subjects are suggested to add relevancy and interest for the student.

### Common Misconceptions

- [http://serc.carleton.edu/NAGTWorkshops/intro/misconception_list.html](http://serc.carleton.edu/NAGTWorkshops/intro/misconception_list.html) This website lists a number of geologic misconceptions for students within the high school and college age group.

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### Diverse Learners

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### Course Content

#### Earth’s History

- **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: Building upon the geologic history found at the middle school level, and the unit above, this topic explores the long-term history of Earth and the analysis of the evidence regarding the rock record (including fossil evidence). Understanding fossil evidence and formation, the different methods, used by scientists to determine the ages of specific events throughout the rock record, requires the use of specific geologic principles.

#### Expectations for Learning: Cognitive Demands

This section provides definitions for Ohio’s science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science.

#### Expectations for Learning: Visions into Practice

Research a specific geologic time period. Document, using specific evidence and data, the environmental conditions,
the climate, the organisms that existed (through fossil evidence), orogenies, continental placement, etc. Present findings orally or in writing.

Investigate the geologic history beneath the school or community using field data, geologic research (published by scientists or through a government agency), and/or bedrock geology maps and reports. Represent findings in a scientific research paper that includes graphics and data analysis or a 3-D (can be virtual) model.

Create a chart or table (can be virtual) to document the pattern of climate change that has occurred throughout geologic time using evidence from the rock record. Use published scientific data (that can be verified and validated) to document periods of climate fluctuation. Evaluate patterns and cause and effect that may be evident in the research. Share the graphic with the class and be prepared to discuss and defend the analysis and interpretation.

Calculate, given the half-life and relative amounts of original isotope and daughter product in a rock sample, the estimated age of the sample (College Board Standards, 2010).

**Instructional Strategies and Resources**

http://climatechange.umaine.edu/Research/projects/byrdglacier.html This site provides a scientific case study of a specific glacier, including quantifiable data that documents measurable changes each year.

http://bprc.osu.edu/ This is the link to the OSU Byrd Polar Research site. There are numerous educational resources that are related to glacial geology and climate change.

http://professionals.collegeboard.com/profdownload/cbscs-science-standards-2009.pdf The college board provides Earth Science recommendations for Earth Science grades 6-12 (beginning on page 21). Essential questions and scientific applications are included in this document to encourage investigation and scientific inquiry. In addition, connections to other topics and subjects are suggested to add relevancy and interest for the student.

**Common Misconceptions**

http://www.epa.gov/climatechange/index.html Students may have misinformation and misconceptions that pertain to climate change. To address this, it is important to provide evidence of climate change throughout Earth’s history and current data to document temperature changes (surface and oceanic). Data and other resources to help with teaching climate change can be found at the EPA website listed above.

http://serc.carleton.edu/introgeo/gallerywalk/misconceptions.html Misconceptions regarding all aspects of geology must be addressed through scientific data analysis, investigation, and research. Discussing the conclusions and findings through a professional “gallery walk” can be a very useful way to determine possible misconceptions that exist for the class and address them.

http://serc.carleton.edu/NAGTWorkshops/intro/misconception_list.html This website lists a number of geologic misconceptions for students within the high school and college age group.

http://serc.carleton.edu/introgeo/earthhistory/geotime.html There are numerous misconceptions regarding Earth’s History so providing scientific data and research for students is essential in addressing them. This website includes a number of strategies and resources that can be used to address Earth History misconceptions.

http://www-istp.gsfc.nasa.gov/istp/outreach/sunearthmiscons.html This website lists common misconceptions for all ages about the Earth and geology.

**Classroom Portals**

http://www.learner.org/resources/series209.html This website shows teaching (in a high school level environmental science class) science using an Earth Systems Science approach.

**Course Content**

**Plate Tectonics**

- Internal Earth
  - Seismic waves
    - S and P waves
    - Velocities, reflection, refraction of waves
  - Structure of Earth (note: specific layers were part of 8th grade)
    - Asthenosphere
    - Lithosphere
    - Mohorovicic boundary (Moho)
    - Composition of each of the layers of Earth
<table>
<thead>
<tr>
<th>Gravity, magnetism, and isostasy</th>
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</thead>
<tbody>
<tr>
<td>Thermal energy (geothermal gradient and heat flow)</td>
</tr>
<tr>
<td>Historical review (note: this would include a review of Continental Drift and Sea-Floor Spreading found in 8th grade)</td>
</tr>
<tr>
<td>Paleomagnetism and magnetic anomalies</td>
</tr>
<tr>
<td>Paleoclimatology</td>
</tr>
<tr>
<td>Plate motion (note: introduced in 8th grade)</td>
</tr>
<tr>
<td>Causes and evidence of plate motion</td>
</tr>
<tr>
<td>Measuring plate motion</td>
</tr>
<tr>
<td>Characteristics of oceanic and continental plates</td>
</tr>
<tr>
<td>Relationship of plate movement and geologic events and features</td>
</tr>
<tr>
<td>Mantle plumes</td>
</tr>
</tbody>
</table>

**Content Elaboration:** In the 8th grade, plate tectonics and Earth's structure are explored. The material from 8th grade should be expanded upon for this unit through adding more detail and depth. Earth's interior and plate tectonics should be investigated using actual seismic data, real-time data, and remote sensing. Relationships between tectonic activity levels and earthquake or volcano predictions should be included. Calculations to obtain the magnitude and exact location of an earthquake should be included. Evidence and data analysis is the key in understanding this part of the Earth system. New technology and discoveries is essential in developing this understanding.

**Expectations for Learning:**

**Cognitive Demands**

This section provides definitions for Ohio's science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science.

**Visions into Practice**

Research and investigate a specific area of ongoing plate movement. Create a presentation (can be virtual) that uses graphics and/or a 3-D model to document the evidence of movement, rate of movement, prediction for future movement, and hazards that may exist due to movement. Authentic scientific data must be collected and analyzed for each part of the research/investigation. Data and data analysis must be included in the documentation.

Investigate contemporary methods of evaluating risk from plate movement (including earthquake and volcanic eruptions). Analyze earthquake and volcano data to identify patterns that can lead to predictability. Document the research in a scientific journal or portfolio (“e-portfolio” can be used also).

Collect real-time data to document tectonic activity in the United States. Highlight the areas of greatest activity, how does this compare to Ohio activity? Determine ways to harness the energy from these areas (research and document existing methods in these areas). Present or discuss findings to the class.

Construct representations of Earth's systems where convection currents occur, identifying areas of uneven heating and movement of matter (College Board Standards, 2010). Use remote sensing or real-time data to determine these zones. Document findings in a scientific report or journal.

**Instructional Strategies and Resources**

http://www.dlese.org/library/query.do?q=&s=0&gr=02 The Digital Library for Earth Systems Education offers resources from a number of sources, such as National Geographic, government agencies, and other scientific agencies. Grade 9-12 resources provided at this link.

http://professionals.collegeboard.com/profdownload/cbcscs-science-standards-2009.pdf The college board provides Earth Science recommendations for Earth Science grades 6-12 (beginning on page 21). Essential questions and scientific applications are included in this document to encourage investigation and scientific inquiry. In addition, connections to other topics and subjects are suggested to add relevancy and interest for the student.

**Common Misconceptions**

http://serc.carleton.edu/NAGTWorkshops/intro/misconception_list.html This website lists a number of geologic misconceptions for students within the high school and college age group.

http://serc.carleton.edu/introgeo/gallerywalk/misconceptions.html Misconceptions regarding all aspects of geology must be addressed through scientific data analysis, investigation, and research. Discussing the conclusions and findings through a professional "gallery walk" can be a very useful way to determine possible misconceptions that exist for the class and address them.
### Diverse Learners

http://www.agiweb.org/earthcomm/

EarthComm is a program that utilizes many different strategies to reach students of all learning levels. The teaching of environmental science through relating the classroom to the real world is essential for many learners.

### Classroom Portals

http://www.learner.org/resources/series209.html  
This website shows teaching (in a high school level environmental science class) science using an Earth Systems Science approach.

### Course Content

#### Earth's Resources

- **Energy resources**
  - Renewable and nonrenewable energy sources and efficiency
  - Alternate energy sources and efficiency
  - Resource availability
  - Mining

- **Air** (primary and secondary air pollution, greenhouse gases)

- **Water** (potable water, importance of wetlands, ground water, hypoxia, eutrophication)

- **Soil** (desertification, mass wasting, sediment contamination)

#### Content Elaboration:

At the advanced science level, 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. 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 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.

#### Expectations for Learning: Cognitive Demands

This section provides definitions for Ohio’s science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science.

#### Expectations for Learning: Visions into Practice

Note: The examples below are also found in the Environmental Science course syllabi.

- Design and build (virtual, blueprint, or 3-D model) an “Eco-House” that utilizes green technology and allows the house to be “off-grid”. Designate a specific location and research/evaluate the different options that would be efficient and effective for that area. Present final product (with complete explanation and defense of choices/options) to the class.

- Design an experiment to determine the amount and size of particulate matter in the air at the school or community. Analyze the results using information from EPA and the Dept. of Health (lung diseases, including emphysema and asthma). Specific Ohio data can be located for the comparative analysis. Report class findings and recommendations orally or in written form to school administrators.

- Investigate local contamination issues. Research existing laws that apply, recommend ways to reduce or prevent contamination (based on scientific data and research), invite community speakers/professionals, collect samples (water, soil, air) to test, document findings, determine a way to share findings with the community, present to an authentic audience.

- Research and collect specific data for a mass wasting or desertification event (can be present day or historical). Research questions should include: what factors lead to the event, what was the result of the event (how was each of Earth’s spheres impacted?), what data is present (analyze the data and draw conclusions), what laws are related to the event, how can this be prevented in the future. Record the results graphically or in a scientific report.

#### Instructional Strategies and Resources

http://www.ngwa.org/  
The National Ground Water Association offers information, data, and resources to support teachers in teaching all aspects of ground water.

http://www.noaa.gov/sciencemissions/bpoilspill.html  
NOAA provides real-time data for many of their projects and research missions.
Each of these links can be used for class discussions and highlighting current event/science in the news. The information is updated weekly or bi-weekly and provides references and resource sites for more in-depth discussion.

This website is a great connection to current events in all topic areas of geology. This includes resources and uses of resources. There are a number of resource links within the document that can help support this topic.

NSTA provides learning modules called “SciPacks” that are designed to increase teacher content knowledge through inquiry-based modules. This module addresses the Earth’s Resources and humans.

Project Wet offers training and resources for K-12 teachers. Promoting deep understanding about all aspects of water and the interconnectedness of all of Earth’s spheres (Earth Systems). Training and workshop opportunities can be found at this link.

The college board provides Earth Science recommendations for Earth Science grades 6-12 (beginning on page 21). Essential questions and scientific applications are included in this document to encourage investigation and scientific inquiry. In addition, connections to other topics and subjects are suggested to add relevancy and interest for the student.

Healthy Water, Healthy People is a Water Quality Educators Guide that offers ideas and resources for teaching all aspects of water and water contamination issues. Ideas for field monitoring and research projects, as well as investigative students are found within the program. Teacher training is also part of the program.

This website lists common high school student misconceptions that deal with renewable energy efficiency. Suggestions are offered to overcome the misconception through exploration and investigation.

This website lists a number of geologic misconceptions for students within the high school and college age group.

Misconceptions regarding all aspects of geology must be addressed through scientific data analysis, investigation, and research. Discussing the conclusions and findings through a professional “gallery walk” can be a very useful way to determine possible misconceptions that exist for the class and address them.

This website shows teaching (in a high school level environmental science class) science using an Earth Systems Science approach.

Course Content

Glacial Geology
- 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
  - 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: Tracing and tracking the glacial history and present-day data for Ohio, the United States, and globally is an emphasis for this unit. Scientific data found in the analysis of the rock 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, research, contemporary science, and technological advances must be included in the study of glacial geology.

Expectations for Learning: Cognitive Demands
This section provides definitions for Ohio’s science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science.

Expectations for Learning: Visions into Practice
Create a cross-section (virtual or drawn) or a 3-D model of a specific type of glacier and use the model or graphic to explain how the glacier moves to the class. Be prepared to explain and defend data and evidence in the demonstration.

Take a field trip to an area of Ohio (check ODNR, State Parks and/or Metro Parks that have access to view glacial features throughout the state) that has visible glacial features, compare the area to maps or satellite data, or visit a scientific center that studies glaciers or glacial formation (such as the Byrd Polar Research Center) to see glacial core data and learn about glaciers from experts (what kind of data is collected and how it is analyzed). Document observations in a scientific journal or paper (including graphics where appropriate).

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 (maps, virtual/aerial documentation, remote sensing data). Relate the history to contemporary evidence of changing climate. Present or discuss findings with the class.

Design and conduct a field study in a local area, or a specific area within Ohio, to collect and/or map evidence of glacial activity (such as collection of glacial erratics, photographic evidence of striations from glacial movement or glacial features). Share and be prepared to defend (with specific data) findings with the class.

Using aerial photographs, LANDSAT data, surficial geology maps, or topographic maps, recognize and identify different types of glaciers and glacier features. Document the types of glaciers graphically and in writing in a scientific journal or portfolio (can be an "e-portfolio").

Instructional Strategies and Resources
http://bprc.osu.edu/ This is the link to the OSU Byrd Polar Research site. There are numerous educational resources that are related to glacial geology and climate change.

http://professionals.collegeboard.com/profdownload/cbcscs-science-standards-2009.pdf The college board provides Earth Science recommendations for Earth Science grades 6-12 (beginning on page 21). Essential questions and scientific applications are included in this document to encourage investigation and scientific inquiry. In addition, connections to other topics and subjects are suggested to add relevancy and interest for the student.

http://www.dnr.state.oh.us/tabid/3501/Default.aspx Project Wet offers training and resources for K-12 teachers. Promoting deep understanding about all aspects of water and the interconnectedness of all of Earth’s spheres (Earth Systems). Training and workshop opportunities can be found at this link.

Common Misconceptions
http://www.epa.gov/climatechange/index.html Students may have misinformation and misconceptions that pertain to climate change. To address this, it is important to provide evidence of climate change throughout Earth’s history and current data to document temperature changes (surface and oceanic). Data and other resources to help with teaching climate change can be found at the EPA website listed above.

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Diverse Learners
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Physical Science: Syllabus and Model Curriculum

Course Description:
Physical Science is a high school introductory-level course which satisfies Ohio Core requirements (ODE, 2008), as required by section 3313.603 of the Ohio Revised Code (ORC). Pacing and sequence is to be determined at the local level. It 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.

Science Inquiry and Application
During the years of grades 9 through 12 all students must use the following 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
- Use technology and mathematics to improve investigations and communications;
- Formulate and revise explanations and models using logic and evidence (critical thinking);
- Recognize and analyze explanations and models; and
- Communicate and support a scientific argument.

Course Content
Study of Matter
- Classification of Matter
  - Heterogeneous vs. homogeneous
  - Properties (chemical & physical)
  - States of matter and its changes
- Atoms
  - Models of the atom (components)
  - Ions (cations and anions)
  - Isotopes
- Periodic Trends of the Elements
  - Periodic Law
  - Representative groups
- Bonding and Compounds
  - Bonding (ionic and covalent)
  - Nomenclature
- Reactions of Matter
  - Chemical reactions
  - Nuclear reactions

Content Elaboration
Classification of Matter
Building upon observation, exploration and analytical skills developed at the elementary and middle school levels, a more extensive knowledge about matter, its composition and the changes its basic particles undergo under various conditions is further constructed. Specific content from middle school, including the particulate nature of matter, elements, compounds, molecules, and kinetic and potential energy, provides the foundational knowledge necessary to understand the concepts in this section. The content at this grade level provides the foundation for topics that will be studied later. For example, concepts in chemistry like electron configuration,
molecular shapes and bond angles will use explanations derived from understanding the phenomena observed in physical science.

Matter can be classified in broad categories such as homogeneous and heterogeneous. It also can be classified according to its composition, such as elements, compounds, and mixtures, or by its chemical and physical properties. Physical properties include color, solubility, odor, hardness, density, melting point and boiling point, viscosity, and malleability. These properties can be used to identify a material, to choose a material for a specific purpose, or to separate the substances in a mixture. The chemical properties, like the reactivity of a substance, can also be studied. These distinctions and categorizations are made to better understand the composition of matter and help predict its behavior under specific conditions.

As studied in middle school, many differences in the physical properties of solids, liquids, and gases are explained by the motion of the particles from which the matter is comprised, and the strength of the forces of attraction between them. Matter can go through a series of phase changes as it is heated or cooled. These changes can be identified by graphing the temperature of a sample versus the time it has been heated. 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. These changes illustrate some of the changes that can occur when energy is absorbed from the surroundings (endothermic), or released into the environment (exothermic). [Back to Study of Matter Outline]

○ **Atoms**

The model of the atom has changed significantly over time. The ancient Greeks envisioned the atom as small, indestructible spheres. More recent models indicate that an atom has a very small nucleus composed of protons and neutrons. Electrons move about in the empty space that surrounds the nucleus and makes up most of the atom. These models expand the concept of the particulate nature of matter, as previously discussed in middle school. Specific experimental evidence that led to the development of atomic models will be studied in Chemistry.

Atomic structure determines the properties of an element and how an atom (of the element) will interact with other atoms. Neutrons have little effect on how an atom interacts with other atoms, but they do affect the mass and stability of the nucleus. Atoms of an element whose nuclei have different numbers of neutrons are called isotopes. Electrons, protons, and neutrons are parts of the atom and have measurable properties, including mass and, in the case of protons and electrons, a characteristic charge. Atoms of an element with a different number of protons and electrons have an unbalanced charge and are called ions. [Back to Study of Matter Outline]

○ **Periodic Trends of the Elements**

When elements are listed in order of increasing number of protons, the same sequence of properties appears over and over again; this is the periodic law. At times the masses do not correspond with periodic order, but the atomic number always does. The periodic table is also arranged so that elements with similar chemical and physical properties are in the same column. Horizontal rows are called periods and vertical columns are called groups or families. Specific names are assigned for representative groups (e.g., alkali metals, alkaline earth metals, halogens and noble gases). Certain families have characteristic ionic charges that will be used later to predict the formulas of compounds. Metals and nonmetals were introduced in middle school. Metalloids are elements that have some properties of metals and some properties of nonmetals. Metals, nonmetals, and metalloids can be identified according to their position on the periodic table. Other trends in the periodic table, including atomic radii and electronegativity are discussed in chemistry. [Back to Study of Matter Outline]
Bonding and Compounds

Bonding describes how atoms are held together in molecules and networks. The interactions between atoms hold them together in molecules or networks; these interactions are identified as chemical bonds. Atoms may be bonded together by losing, gaining or sharing electrons. When two atoms transfer an electron between them, the atom that gains the electron becomes a negative ion (anion) and the atom that loses the electron becomes a positive ion (cation). The oppositely charged ions attract each other and form an ionic bond. Most of the time, an ionic bond is formed between a metal and a nonmetal. Covalent bonds result from the sharing of electrons between two atoms. A covalent bond is usually formed between two nonmetals. The bonds in most compounds fall on a continuum between the two extreme models of bonding: ionic and covalent. Prediction of bond types from electronegativity values and polar covalent bonds are studied in chemistry.

The formula of a compound depicts its composition. The subscripts in the formula of a compound give the ratio of the atoms or ions in the compound. When writing the formula for ionic substances, subscripts (simplest whole number ratio) are added so that the sum of the charges adds up to zero. When there is more than one polyatomic ion, the entire formula for the ion is placed in parentheses with a subscript outside the parentheses to indicate the number of ions. For example, magnesium nitrate is Mg(NO$_3$)$_2$. For assessment purposes, at this level, students will be given the formula and charge of any polyatomic ion used as well as charges for metals that have more than one ionic state (e.g., Fe$^{+2}$ or Fe$^{+3}$). Knowing specific names, formulas, and charges of common polyatomic ions from memory is reserved for chemistry.

Different rules of nomenclature are used when naming ionic and covalent compounds. Ionic compounds like sodium chloride (NaCl) and calcium iodide (CaI$_2$) are so named based on a predictable pattern: the name of the cation is followed by the name of the anion (using the -ide suffix, when appropriate). Naming compounds that are formed with metals that have more than one ionic state is reserved for chemistry. For covalent compounds, the symbols for the elements are written in the order the elements appear in the name and then prefixes are added to indicate the number of atoms each element present in the molecule (e.g., diphosphorus pentoxide is P$_2$O$_5$). When there is no prefix for the first element, it is assumed only one atom is present, since the prefix “mono-” is not used for the first element in the compound. Naming organic molecules is beyond this grade level and is reserved for an advanced chemistry course. Prefixes will be limited to represent values from one to ten. [Back to Study of Matter Outline]

Reactions of Matter

During chemical reactions, energy is either released to the environment (exothermic), or absorbed from the environment (endothermic). As learned in middle school, matter is always conserved in all chemical and nonchemical processes therefore it is never created or destroyed. In a chemical reaction, the number and type of atoms and the total mass are the same before and after the reaction.

Chemical reactions can also be studied by using equations to represent how the arrangement of atoms in the reactants rearranges to form the products. During the reaction, the number and type of atoms remain the same. This conservation of matter is represented by a balanced equation. Given the formulas of the reactants and products, equations can be balanced by adding coefficients, which represent how many units of the substance are involved in the reaction. Balanced equations can also be written from a word description of the reaction. At this level, reactants and products can be identified from an equation and simple equations can be written and balanced. For example, nitrogen gas plus oxygen gas yields nitrogen dioxide gas can be expressed as N$_2$(g) + 2O$_2$(g) $\rightarrow$ 2NO$_2$(g). More complex stoichiometric relationships and classification of types of chemical reactions and is reserved for chemistry.

While chemical changes involve changes in how the electrons are transferred or shared, nuclear reactions involve changes to the nucleus, and therefore the protons and neutrons. The strong nuclear force is the attractive force that binds protons and neutrons together in the nucleus. Over very short distances this force is much greater than the electrical forces among protons. However, the greater the number of protons in a
nucleus, the greater the electrical force that repels those protons. When the attractive and repulsive forces in the nucleus are not balanced, the nucleus becomes unstable and emits particles and energy. Such nuclei are said to be radioactive. The time that is required for one half of a sample of radioactive material to decay is known as the half-life of the material. Half-life values are used in radioactive dating, a method of calculating the age of samples by measuring its levels of carbon-14 (comparing the objects’ carbon-14 levels with carbon-14 levels in the atmosphere). Further details about nuclear reactions, like common types of nuclear radiation and balancing nuclear equations are reserved for chemistry.

More examples of nuclear reactions include nuclear fission and nuclear fusion. Nuclear fission involves the decay, or splitting, of large nuclei into smaller nuclei, releasing large quantities of energy. Nuclear fusion is the joining of nuclei into a larger nucleus accompanied by the release of large quantities of energy. Nuclear fusion is the process responsible for the formation of stars, formation of all the elements in the universe beyond helium, and the energy of the Sun. Detailed instruction about fission and fusion processes is outside of the boundary for this grade level and is reserved for advanced science courses, (i.e., Astronomy).

### Expectations for Learning: Cognitive Demands

This section provides definitions for Ohio’s science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science.

### Expectations for Learning: Visions into Practice

This section provides examples of tasks that students may perform; this includes guidance for developing classroom performance tasks and assessments. It is not an all inclusive checklist of what should be done, but is a springboard for generating innovative ideas.

### Investigate the material that make up the composition of a tennis ball; determine what makes it bounce the highest (and, or travel farthest); compare brands; analyze the data, draw conclusions and present your findings in multiple formats.

### Current nuclear power plants generate electricity from fission and use heavy elements such as uranium for fuel. The technology is not currently available for fusion power plants. Fusion would use lighter elements such as hydrogen for fuel. Investigate the availability and use of energy from each type of power plant and make a claim in defense of which would be the better choice for use over the other. Use data analysis, presented in multiple formats, for evidence to defend your claim.

### Instructional Strategies and Resources: This section provides additional support and information for educators. These are strategies for actively engaging students with the topic and for providing hands-on minds-on observation and exploration of the topic, including authentic data resources for scientific inquiry, experimentation and problem-based tasks that incorporate technology and technological and engineering design. Resources selected are printed or web-based materials that directly relate to the particular Content Statement. It is not intended to be a prescriptive list of lessons.

**The World of Chemistry** is a video instructional series comprising 26 half-hour video programs for college and high school classrooms and adult learners produced by the University of Maryland and the Educational Film Center with Annenberg Media ©. Titles include: Measurement: The Foundation of Chemistry; Modeling the Unseen; A Matter of State; The Atom; The Periodic Table; Chemical Bonds;; Metals; Futures

### Common Misconceptions

Students may think that models are physical copies of the real thing, failing to recognize models as conceptual representations. (AAAS, 1993)

Students know models can be changed, but at the high school level they may be limited by thinking that a change in a model means adding new information, or that changing a model means replacing a part that was wrong. (AAAS, 1993)

Students often do not believe models can duplicate reality. (AAAS, 1993)

When multiple models are presented, they tend to think there is one “right one”. (AAAS, 1993)

### Diverse Learners
Classroom Portals
This series of videos on demand show classroom strategies for implementing inquiry into the high school classroom. While not all of the content is aligned to physical science, the strategies can be applied to any content.

Course Content
Energy and Waves
- Conservation of Energy
  - Quantifying Kinetic Energy
  - Quantifying Gravitational Potential Energy
  - Energy is relative
- Transfer and Transformation of Energy (including work)
- Waves
  - Characteristics (speed, wavelength, frequency)
  - Behavior
    - Energy transfer
    - Refraction, Reflection, Diffraction, Absorption, Superposition
    - Doppler shift

Content Elaboration
Building upon knowledge gained in elementary and middle school, major ideas 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.

- Conservation of Energy
  Energy is a scalar quantity and has units of Joules (J). As learned in middle school, energy is always conserved. For closed systems in which no energy is transferred into or out of the system, the total initial energy of the system is equal to the total final energy of the system. In middle school the concepts of kinetic and potential energy were introduced. In physical science kinetic energy and gravitational potential energy are quantified and used to calculate values associated with energy (i.e., height, mass, speed). Kinetic energy, \( E_k \), can be mathematically represented by \( E_k = \frac{1}{2}mv^2 \), where \( m \) and \( v \) are the mass and speed of the object. Gravitational potential energy, \( E_g \), can be mathematically represented by \( E_g = mgh \), where \( g = 9.8 \text{ m/s}^2 \), and \( m \) and \( h \) are the mass and height of the object above a reference point. The amount of 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. [Back to Energy and Waves outline]

- Transfer and Transformation of Energy
  In middle school, the concepts of energy transfer and transformation are introduced, including conservation of energy, conduction, convection, and radiation, the transformation of electrical energy, and the dissipation of energy into heat. When an outside force moves an object over a distance, energy has been transferred either into or out of the system. As learned in middle school, this method of energy transfer is called work. As long as the force, \( F \), and displacement, \( \Delta x \), are in the same direction, work, \( W \), can be calculated from the equation \( W = F\Delta x \). 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. [Back to Energy and Waves outline]

- Waves
  As learned in middle school, waves transmit energy from one place to another, can transfer energy between objects, obey the law of conservation of energy, and can be described by their speed, wavelength, frequency, and amplitude. 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 (\( v_{\text{wave}} \)) depends on the nature of the material (e.g., waves travel faster through solids than gases). For a particular uniform medium, as the frequency \( (f) \) of the wave is increased, the wavelength \( (\lambda) \) of the wave is decreased. The mathematical representation is \( v_{\text{wave}} = \lambda f \). [Back to Energy and Waves outline]
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. This interaction is called absorption. Waves can bounce off solid barriers. This interaction is called reflection. When a wave travels form one material (medium) into another material, its direction may change. This interaction is called refraction. Waves may bend around small obstacles or openings. This interaction is called diffraction. When two waves traveling through the same medium meet, they pass through each other then continue traveling through the medium as before. When the waves meet and occupy the same part of the medium, the displacement of the two waves adds algebraically. This interaction is called superposition. In physics, many of these wave phenomena will be studied further and quantified. [Back to Energy and Waves outline]

The wavelength and observed frequency of a wave depends upon the relative motion of the source and the observer. If either is moving toward the other, the wavelength is shorter and the observed frequency is higher; if either is moving away, the wavelength is longer and the observed frequency is lower. This phenomenon is called the Doppler shift. Calculations to measure the apparent change in frequency or wavelength are not appropriate at this grade level. [Back to Energy and Waves outline]

### Expectations for Learning: Cognitive Demands
This section provides definitions for Ohio’s science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science.

### Expectations for Learning: Visions into Practice
This section provides examples of tasks that students may perform; this includes guidance for developing classroom performance tasks and assessments. It is not an all inclusive checklist of what should be done, but is a springboard for generating innovative ideas.

**Design, build, and test a ramp system onto which a ball can be placed so that it rolls down a ramp and continues a specific distance on the table. Describe what properties of the system were important (and those not important) in the design. Different target distances will be given such that the launched ball will travel the designed course and hit the given target within three trials.**

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; give evidence to support any claims. Compare results with other groups to determine similarities and differences. Propose explanations for any differences that are observed.

### Instructional Strategies and Resources
This section provides additional support and information for educators. These are strategies for actively engaging students with the topic and for providing hands-on minds-on observation and exploration of the topic, including authentic data resources for scientific inquiry, experimentation and problem-based tasks that incorporate technology and technological and engineering design. Resources selected are printed or web-based materials that directly relate to the particular Content Statement. It is not intended to be a prescriptive list of lessons.

This site has a downloadable document giving strategies for teaching different models of energy and addressing misconceptions about energy.

This site links to many animations of waves that can be used with absent students or students who need more reinforcement.

Modeling workshops are available nationally that helps teachers develop a framework for using guided inquiry in their instruction.

### Common Misconceptions
This site describes common, pervasive misconceptions about energy. Misconceptions that pertain to this content level and grade level include: Students believe potential energy is a thing that objects hold (like cereal stored in a closet). Students believe that the only type of potential energy is gravitational. Students believe that doubling the velocity of a moving object will double its kinetic energy. Students believe stored energy is something that causes energy later. It is not energy until it has been released. Students believe objects do not have any energy if they are not moving. Students believe energy is a thing that can be created and destroyed.
Students believe energy is literally lost in many energy transformations. Students believe gravitational potential energy depends only upon the height of an object. Students believe energy can be changed completely from one form to another with no loss of useful energy.

Diverse Learners

Classroom Portals

This series of videos on demand produced by Annenberg shows classroom strategies for implementing inquiry into the high school classroom. While not all of the content is aligned to physical science, the strategies can be applied to any content.

Course Content

Forces and Motion

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

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

- **Dynamics** (how forces affect motion)
  - Objects at rest
  - Objects moving with constant velocity
  - Accelerating objects

Content Elaboration

Building upon knowledge gained in elementary and middle school, major ideas of motion and forces are further developed. In middle school, speed has been dealt with conceptually, mathematically and graphically. The ideas that forces have both magnitude and direction, can be represented with a force diagram, can be added to find a net force, and may affect motion have also been discussed. In physical science mathematics, including graphing, is used when describing these phenomena, moving from qualitative understanding to one that is more quantitative. At this level, all motion is limited to objects moving in a straight line either horizontally, vertically, up an incline, or down an incline.

- **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 because they have both 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, and only inertial frames of reference will be used. [Back to Outline]

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. [Back to Outline]

Velocity is a vector property 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 and is not always equal to the speed. Examples should be given where 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 velocity of an object at any instant (clock reading) is called instantaneous velocity. An object may not travel at this instantaneous velocity for any period of time or cover any distance with that particular velocity,
especially if the velocity is continually changing. [Back to Outline]

Acceleration is a vector property that represents the rate at which velocity changes. Average acceleration can be calculated by dividing the change in velocity divided by elapsed time \(a_{\text{avg}} = (v_f - v_i)/(t_f - t_i)\). 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 reserved for physics. The word “deceleration” should not be used because students tend to associate a negative sign of acceleration only with slowing down. 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. [Back to Outline]

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 physical science, graphs will be excluded to positive x-values and show only uniform motion involving constant velocity or constant acceleration.

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 straight 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.

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 constant velocity) will have a straight horizontal line for a velocity vs. time graph. Average acceleration can be by determining 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. [Back to Outline]

- **Forces**

  Forces are used to understand motion through Newton’s Laws. Force is a vector quantity, having both magnitude and direction. 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/s². A Newton can also be represented as kg·m/s². Friction and normal forces are introduced conceptually at this level. These forces and other forces discussed in prior grades (contact, gravitational, electric and magnetic) can be used as examples of forces that affect motion. Gravitational force (weight) can be calculated from mass, but all other forces will only be quantified from force diagrams that were introduced in middle school. In physical science, only forces in one-dimension (positive and negative) will be addressed. The net force can be determined by one-dimensional vector addition. More quantitative study of friction forces, universal gravitational forces, elastic forces, electrical forces, and magnetic will occur in physics. [Back to Outline]

  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 a direction opposite to the relative motion of the object. In nearly all commonly experienced situations, friction complicates the understanding of motion, although the basic principles still apply when friction is considered. In physical science, friction will only be calculated from force diagrams. Equations for static and kinetic friction will be discussed in physics. [Back to Outline]

  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 magnet attached to a refrigerator). A normal force is always a push directed at right angles from the surface of the interacting objects. A tension force occurs when a non-slack rope, wire, cord, or similar device pulls on another object. The tension force always points in the direction the device is pulling. [Back to Outline]

  Gravitational, magnetic, and electrical forces occur even when objects are not touching. No substance is required between the interacting objects; these are called forces at a distance. The field model is used to represent forces at a distance and is described by regions of influence called fields that surround objects.
When an object with the appropriate property (mass for gravitational fields, charge for electric fields, a magnetic object for magnetic fields) enters the field, the field exerts a force on it (e.g., a magnet moving a compass needle). 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. For objects near Earth’s surface weight, $F_g$, can be calculated from the equation $F_g = mg$ where $g = 9.8 \text{ m/s}^2$. [Back to Outline]

Dynamics

An object does not accelerate (remains at rest or maintains a constant speed and direction of motion) unless 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 applied forces (net force) and inversely proportional to the mass ($a = \frac{F_{net}}{m}$). When the vector sum of the forces (net force) 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. These laws will be applied to systems consisting of a single object. In physics, Newton's third law will be introduced and all laws will be applied to systems of many objects. [Back to Outline]

Expectations for Learning: Cognitive Demands

This section provides definitions for Ohio’s science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science.

Expectations for Learning: Visions into Practice

This section provides examples of tasks that students may perform; this includes guidance for developing classroom performance tasks and assessments. It is not an all inclusive checklist of what should be done, but is a springboard for generating innovative ideas.

Predict the position a buggy traveling at constant speed from the bottom of a ramp will collide with a cart accelerating from rest from the top of the ramp. All data, graphs, calculations, and explanations must be clearly represented and annotated to explain how the answer was determined. The cart and the buggy may be checked out one at a time to collect data, but may not be used together until the prediction is ready to be tested. Conclude this project by actually testing the prediction and then analyzing possible prediction errors.

Investigate the relationship between position and time for a cart that rolls down a ramp from rest. Graph the results. Make a claim about how position and time are related and use evidence to support the claim. Present the findings to the class. Based on the presentations of other investigations, propose sources of error and provide suggestions for how the experiments can be improved.

Instructional Strategies and Resources: This section provides additional support and information for educators. These are strategies for actively engaging students with the topic and for providing hands-on minds-on observation and exploration of the topic, including authentic data resources for scientific inquiry, experimentation and problem-based tasks that incorporate technology and technological and engineering design. Resources selected are printed or web-based materials that directly relate to the particular Content Statement. It is not intended to be a prescriptive list of lessons.

This simulation allows students to explore the forces at work when trying to push a filing cabinet. An applied force is created and the resulting friction force and total force acting on the cabinet are then shown. Forces vs. time, position vs. time, velocity vs. time, and acceleration vs. time graphs can be shown as can force diagrams representing all the forces (including gravitational and normal forces).

This link gives a thorough explanation of acceleration, including an animation to use with students who may still be having difficulties with acceleration.

Modeling workshops are available nationally that help teachers develop a framework for incorporating guided inquiry in their instruction.

Common Misconceptions

This site addresses common misconceptions about motion including: Students think that if the speed is constant then there is no acceleration. Students think that high velocities coincide with large accelerations.
and low velocities coincide with small accelerations.

**Diverse Learners**

**Classroom Portals**

This series of videos on demand produced by Annenberg, shows classroom strategies for implementing inquiry into the high school classroom. While not all of the content is aligned to physical science, the strategies can be applied to any content.

**Course Content**

**The Universe**
- History of the Universe
- Galaxy formation
- Stars
  - Formation; stages of evolution
  - Fusion in stars
- Earth and the Solar System

**Content Elaboration**

Building a unified understanding of the universe from elementary and middle school science, insights from history, and mathematical ways of thinking, provides a basis for knowing the nature of the universe. Concepts from the previous section, Forces, Motion and Energy, are also used as foundational knowledge. The role of gravity in forming and maintaining the organization of the universe becomes clearer at this level, as well as the scale of billions and speed of light used to express relative distances. Instructional content includes:

- **History of the Universe**

  The origin of the universe remains one the greatest questions in science. Mathematical models and computer simulations are used in studying evidence from many sources in order to form a scientific account of the universe. Astronomers theorize that the universe came into being at a single moment, in an event called the big bang. The big bang theory places the origin of the universe at approximately 13.7 billion years ago when the universe began as a hot, dense, chaotic mass. According to this theory, the universe has been expanding ever since. After the big bang, the universe expanded quickly and then cooled down enough for atoms to form. Gravity pulled the atoms together into gas clouds that eventually evolved into stars, which comprise young galaxies.

  When physicists noticed a signal on their radio telescope they eventually realized that they were detecting a faint distant glow in every direction. This led to the discovery of the cosmic microwave background radiation, radiation from the original big bang that is still traveling through the universe. This radiation is evidence that supports the big bang theory thereby explaining the expansion of the observable universe.

  Increasingly sophisticated technology is used to learn about the universe. Visual, radio, and x-ray telescopes collect information from across the entire electromagnetic spectrum; computers handle data and complicated computations to interpret them; space probes send back data and materials from remote parts of the solar system; and accelerators provide subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed. [Back to Earth and the Universe Outline]

- **Galaxy formation**

  A galaxy is a huge group of individual stars, star systems, star clusters, dust, and gas bound together by gravity. There are billions of galaxies in the universe, and they vary in size and shape. There are three main types, as classified by astronomers, disk (spiral and barred-spiral), elliptical, and irregular. The Milky Way, a spiral galaxy, is the name of our galaxy. It has more than 100 billion stars and a diameter of more than 100,000 light years. At the center of our galaxy is a bulge of stars, from which are spiral arms of gas, dust, and most of the young stars. The entire galaxy is also surrounded by an enormous halo of globular clusters.

  Looking at other galaxies, astronomers are able to measure their motion using red shift. Hubble’s Law is that
galaxies that are farther away have a greater red shift, thus, the speed at which a galaxy is moving away is proportional to its distance from us. 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. Thus, as previously stated, all of this supports the big bang theory. [Back to Earth and the Universe Outline]

- **Stars**
The process of star formation and evolution continues in a cycle of matter in the universe that is very efficient. Stars form by condensing due to gravity out of clouds of molecules of the lightest elements. As the clouds collapse, the density and temperature in the core of the newly forming star increase until nuclear fusion of the light elements into heavier ones can occur. Fusion releases great amounts of energy. Because of the amounts of light elements in the cores of stars, these reactions can continue to occur for millions or billions of years. Eventually, the most massive stars explode, producing clouds containing heavy elements from which other stars could later condense. Unlike the sun, most stars are in systems of two or more stars orbiting around one another.

**Stars like the Sun**, transform matter into energy in nuclear reactions in their cores. When hydrogen nuclei fuse to form helium, a small amount of matter is converted to energy. This production of heavier elements from lighter elements by stellar fusion has never ceased and continues today. These and other fusion processes in stars have led to the formation of all the other elements.

**Stars are classified by their color, size, brightness and mass.** Astronomers use a Hertzprung-Russell diagram to estimate the sizes of stars and predict how stars will change over time. The H-R diagram is a graph of the surface temperature, or color, and absolute brightness of a sample of stars. Astronomers have found that most stars fall on the main sequence of the H-R diagram, a diagonal band running from the bright hot stars on the upper left to the dim cool stars on the lower right. A star's mass determines the star's place on the main sequence and how long it will stay there. Also, in accordance with the H-R diagram, the size and surface temperature can be estimated thereby identifying the stage of evolution for the star (protostar, main sequence, red giant, white dwarf, black dwarf, and supergiant). For low-mass stars, the evolutionary sequence is: protostar, main sequence, red giant, planetary nebula, white dwarf, black dwarf. For high-mass stars, the evolutionary sequence is: protostar, main sequence, red giant, supergiant, supernova, neutron star (but for the most massive stars, the end stage is black hole). [Back to Earth and the Universe Outline]

- **Earth and the solar system**
Our solar system (including our sun) coalesced out of a giant cloud of gas and debris left in the wake of exploding stars about five billion years ago and is located about 2/3 of the way out from the center of the Milky Way. As Earth and other planets formed, the heavier elements coalesced in their centers. On terrestrial planets closest to the sun (Mercury, Venus, Earth, and Mars) the lightest elements were mostly removed by radiation from the newly formed sun; on the outer planets (Jupiter, Saturn, Uranus and Neptune), the lighter elements still surround them as deep atmospheres of icy, dense gas. Everything in and on Earth, including living organisms, is made of the material from the original cloud.

Earth is part of a solar system and has unique characteristics based on its position. Planetary differentiation is a process in which more dense materials of a planet sink to the center, while less dense materials stay on the surface. A major period of planetary differentiation occurred approximately 4.6 billion years ago. Earth’s position relatively close to the sun, puts it within the habitable zone of a star like our sun. Venus and Mars are also in the habitable zone of our sun. [Back to Earth and the Universe Outline]

**Expectations for Learning: Cognitive Demands**
This section provides definitions for Ohio’s science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science.

**Expectations for Learning: Visions into Practice**
This section provides examples of tasks that students may perform; this includes guidance for developing classroom performance tasks and assessments. It is not an all inclusive checklist of what should be done, but
Federal funding agencies form committees to decide which telescope projects will receive funds for construction. Recommend to the committee which of the following projects should be funded (Project 1, or Project 2) based on your evaluation of data analyzing the penetration ability of Gamma radiation, X-rays, UV, Visible light, Infrared and Radio wavelengths, and the following considerations (Prather, et al, 2008): certain wavelengths of light are blocked from reaching Earth’s surface by the atmosphere; how efficiently telescopes work at different wavelengths; telescopes in space are much more expensive to construct than Earth-based telescopes. 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”).

### Instructional Strategies and Resources

This section provides additional support and information for educators. These are strategies for actively engaging students with the topic and for providing hands-on minds-on observation and exploration of the topic, including authentic data resources for scientific inquiry, experimentation and problem-based tasks that incorporate technology and technological and engineering design. Resources selected are printed or web-based materials that directly relate to the particular Content Statement. It is not intended to be a prescriptive list of lessons.

#### Astronomy: Eliciting Student Ideas (90 min.)
Introduces constructivism by examining student beliefs on what causes the seasons and their explanations for the phases of the moon. ([www.learner.org](http://www.learner.org))

**The Quantum Mechanical Universe** is a video about a current look at where we’ve been and a peek into the future. ([www.learner.org](http://www.learner.org))

**Dying stars and Birth of Elements** ([http://www3.gettysburg.edu/~marschal/clea/Dyingstarslab.html](http://www3.gettysburg.edu/~marschal/clea/Dyingstarslab.html)) is a computer-based exercise where high school students analyze realistically simulated X-ray spectra of a supernova remnant and determine the abundances of various elements in them. In the end, they will find that the elements necessary for life on Earth—the iron in their blood, the calcium in their bones—are created in these distant explosions.

**Solar System Activities for the classroom** is an aid for building lessons on the topic of the Solar System.

Details about star formation -[http://www.windows2universe.org/headline_universe/olpa/stars_01july10.html](http://www.windows2universe.org/headline_universe/olpa/stars_01july10.html)  
[http://www.windows2universe.org/the_universe/Stars.html](http://www.windows2universe.org/the_universe/Stars.html)

**Exploring Mars** is a video showing students in an 11th-grade integrated science class who explore how the Mars landscape may have formed. ([www. learner.org](http://www.learner.org))

#### Common Misconceptions

Students may believe that the world has always been the way it is now and any changes that occurred were sudden and comprehensive (Freyberg, 1985).

Scale drawings help students understand how the distances to the Moon and the Sun were estimated and why the stars must be very far away (AAAS, 1993, p.63).

Students’ understanding of the magnitude of the universe needs to developed where they have can make sense of how large is a billion or a million. Keely, Eberle & Tugel (2005) suggests teaching the notion of scale with familiar objects that students can see, like the Moon and Sun. Gradually introduce the nearby planets and then planets further away.(p.182)

#### Diverse Learners

#### Classroom Portals

This series of videos on demand show classroom strategies for implementing inquiry into the high school classroom. While not all of the content is aligned to physical science, the strategies can be applied to any content.
Physics Syllabus and Model Curriculum

Course Description:

Physics is a high school level course which satisfies Ohio Core science graduation requirements as required by section 3313.603 of the Ohio Revised Code which require inquiry-based laboratory experiences that engage 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.

The following information may be taught in any order. The sequence provided here does not represent the ODE-recommended sequence as there is no ODE-recommended sequence.

Science Inquiry and Application

During the years of grades 9 through 12 all students must use the following 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;
- Use technology and mathematics to improve investigations and communications;
- Formulate and revise explanations and models using logic and evidence (critical thinking);
- Recognize and analyze explanations and models; and
- Communicate and support a scientific argument.

Course Content

Motion

- Graph Interpretations
  - Position vs. time
  - Velocity vs. time
  - Acceleration vs. time
- 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)
- Projectiles
  - Independence of horizontal and vertical motion
  - Problem-solving involving horizontally launched projectiles

Content Elaboration

The concepts of displacement, velocity and acceleration that were introduced in physical science are developed further. Mathematics, including graphing that was introduced in middle school and further developed in physical science, becomes increasingly more complex. As studied in middle school and physical science, motion can be represented by position vs. time graphs and velocity vs. time graphs. Acceleration vs. time graphs are introduced in physics. Specifics about the velocity, speed, direction, and change in motion can be determined by interpreting such graphs. In physical science, only straight-line motion was investigated and graphing was limited to situations involving either uniform velocity or uniform acceleration. In physics, more complex graphs will be used 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). 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.

- **Position vs. Time 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 that are speeding up will become steeper as they progress and the position vs. time graph for objects slowing down will become less steep. [Back to Motion Outline]

- **Velocity vs. Time Graphs**
  On a velocity vs. time graph, objects that are speeding up will slope away from the x-axis and objects that are slowing down 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 displacement. [Back to Motion Outline]

- **Acceleration vs. time graphs**
  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. [Back to Motion Outline]

- **Uniform acceleration problems**
  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 kinematics equations to solve increasingly complex problems, including those involving free fall with negligible air resistance in which objects fall with uniform acceleration. On the surface of the earth, in the absence of other forces, the acceleration of freely-falling objects is 9.81 m/s\(^2\). [Back to Motion Outline]

- **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. [Back to Motion Outline]

**Expectations for Learning: Cognitive Demands**

This section provides definitions for Ohio’s science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science.

**Expectations for Learning: Visions into Practice**

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A buggy moving at constant velocity is released from the top of a ramp 1.0 second before a cart that starts from rest and accelerates down the ramp. At what position on the ramp will the buggy and the cart collide? All data, graphs, calculations, and explanations must be clearly represented and annotated to explain how the answer was determined.
The cart and the buggy may be checked out one at a time to collect data, but may not be used together until the prediction is ready to be tested.

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.

**Instructional Strategies and Resources**: This section provides additional support and information for educators. These are strategies for actively engaging students with the topic and for providing hands-on minds-on observation and exploration of the topic, including authentic data resources for scientific inquiry, experimentation and problem-based tasks that incorporate technology and technological and engineering design. Resources selected are printed or web-based materials that directly relate to the particular Content Statement. It is not intended to be a prescriptive list of lessons.

"Moving man" is an interactive simulation from PhET that allows students to set position, velocity and acceleration, watch the motion of the man and see the position vs. time, velocity vs. time and acceleration vs. time graphs.

"Motion in 2-D" is an interactive simulation from PhET that shows the magnitude and direction of the velocity and accelerations for different types of motion.

**Common Misconceptions**

This site lists common misconceptions for many physics topics, including these that pertain to motion: Two objects side by side must have the same speed. Acceleration and velocity are always in the same direction. Velocity is a force.

If velocity is zero, then acceleration must be zero too. Heavier objects fall faster than light ones. Acceleration is the same as velocity. The acceleration of a falling object depends upon its mass. Freely falling bodies can only move downward. There is no gravity in a vacuum. Gravity only acts on things when they are falling.

This site lists common misconceptions about motion including: Students think that when the velocity is constant so is the acceleration and do not realize that the acceleration is zero. Students think that if the speed is constant there is no acceleration. Students think that a positive acceleration is always associated with speeding up and a negative acceleration is always associated with slowing down.

**Diverse Learners**

**Classroom Portals**

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**Course Content**

**Forces, Momentum and Motion**

- Newton’s Laws applied to complex problems
- Gravitational Force and Fields
- Friction Force (static and kinetic)
- Elastic forces
- Forces in two-dimensions
  - Adding vector forces
  - Motion down inclines
  - Centripetal forces and circular motion
- Momentum, impulse and conservation of momentum

**Content Elaboration**

- Newton’s Laws

Building upon knowledge gained in middle school and physical science, gravitational forces are studied as a universal phenomenon. Elastic forces, air resistance and friction are included at this level. Newton’s laws of motion are applied to mathematically describe and predict the effects of forces on the two-dimensional motions of objects and to analyze objects in free fall that experience significant air resistance. Newton’s third law is introduced and used as a tool to solve complex problems involving systems of objects. The vector properties of momentum and impulse are
introduced and used to analyze elastic and inelastic collisions between objects.

A force is an interaction between two objects; both objects in the interaction experience an equal amount of force, but in opposite directions. This concept can be used to solve complex problems that involve systems of many objects that move together as one. The equation \( \mathbf{a} = \frac{\mathbf{F}_{\text{net}}}{m} \) 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).

- **Gravitational forces and fields**
  Gravitational force is an attraction between masses. As learned in middle school, the strength of the force is proportional to the masses and weakens rapidly with increasing distance between them. It is very weak compared to other interactions and is 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, \( F_g = \left(\frac{G \cdot m_1 \cdot m_2}{r^2}\right) \). The proportionality constant, \( G \), is called the universal gravitational.

  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, \( g = \frac{F_g}{m} \). However, 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 since gravitational fields only produce attractions. If the gravitational field at a certain position is known, then the gravitational force exerted by the source of that field on any object at that position can be calculated by multiplying the gravitational field and the mass of the object. Gravitational fields can be represented by field diagrams obtained by plotting field arrows at a series of locations.

  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.

- **Friction forces**
  Kinetic friction acts between two surfaces that are sliding relative to each other and always acts in a direction that opposes the relative motion of the object. 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 \( \mu_k \) is the coefficient of kinetic friction that depends upon the materials the two surfaces are made of.

  Sometimes friction forces can prevent object from sliding past each other, even when an external force is applied parallel to the two surfaces that are in contact. This friction force is called static friction, which is mathematically represented by \( F_s \leq \mu_s F_N \). 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, \( F_{\text{max}} = \mu_s F_N \). 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.

- **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 \( F_{\text{elastic}} = k\Delta x \), where \( \Delta x \) 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.

- **Adding Vector Forces**
  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.
• **Inclines**
The net force, final velocity, time, displacement, and acceleration can be calculated for objects on frictionless inclines.

• **Circular motion**
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 in 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 are result from the force of gravity. Centripetal acceleration is directed toward the center of the circle and can be calculated by the equation \( a_c = \frac{v^2}{r} \), 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. [Back to Forces and Momentum Outline]

• **Momentum, Impulse and Conservation of Momentum**
The concept of linear momentum can describe moving objects. Momentum, \( p \), is a vector quantity that is directly proportional to both 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. This can be mathematically represented by \( \sum p_i = \sum p_f \). For assessment purposes, momentum may be dealt with in two dimensions conceptually, but calculations will only be done in one dimension.

Impulse, \( \Delta p \), is the total momentum transfer into or out of a system and is equal to the change in momentum for the system. Any transfer is the result of interaction(s) 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, \( \Delta t \). It can mathematically be represented by \( \Delta p = p_f - p_i = F_{avg} \Delta t \).

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 breaks for a long period of time). [Back to Forces and Momentum Outline]

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| Given two spring-loaded dynamics carts with different masses that are located on the table between two wooden blocks, determine where the carts must be placed so that they hit the blocks simultaneously. Measurements may be taken of the model set up at the front of the room, but the carts may not be released at this time. Clearly justify the answer and state any assumptions that were made. Test your prediction with the model set up at the front of the room. |

| 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. |

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Ohio Department of Education, February 2011 Draft
“Collision Lab” is an interactive simulation that allows students to investigate collisions on an air hockey table. Students can vary the number of discs, masses, elasticity and initial conditions to see if momentum and kinetic energy are conserved.

“Forces and Motion” is an interactive simulation that allows students to explore the forces present when a filing cabinet is pushed. Students can create an applied force and see the resulting friction force and total force acting on the cabinet. Graphs show the forces vs. time, position vs. time, velocity vs. time, and acceleration vs. time. A force diagram of all the forces (including gravitational and normal forces) is shown.

Common Misconceptions
This site lists common misconceptions for many physics topics. Those pertaining to forces, momentum and motion include: Forces are required for motion with constant velocity. Inertia deals with the state of motion (at rest or in motion). All objects can be moved with equal ease in the absence of gravity. All objects eventually stop moving when the force is removed. Inertia is the force that keeps objects in motion. If two objects are both at rest, they have the same amount of inertia. Velocity is absolute and not dependent on the frame of reference. Action-reaction forces act on the same body. There is no connection between Newton's Laws and kinematics. The product of mass and acceleration, ma, is a force.

Fiction can't act in the direction of motion. The normal force on an object is equal to the weight of the object by the 3rd law. The normal force on an object always equals the weight of the object. Equilibrium means that all the forces on an object are equal. Equilibrium is a consequence of the 3rd law. Only animate things (people, animals) exert forces; passive ones (tables, floors) do not exert forces. Once an object is moving, heavier objects push more than lighter ones. Newton's 3rd law can be overcome by motion (such as by a jerking motion). A force applied by an object, like a hand, still acts on an object after the object leaves the hand. The Moon is not falling. The Moon is not in free fall. The force that acts on apples is not the same as the force that acts on the Moon. The gravitational force is the same on all falling bodies. There are no gravitational forces in space. The gravitational force acting on the Space Shuttle is nearly zero. The gravitational force acts on one mass at a time.

Moon stays in orbit because the gravitational force on it is balanced by the centrifugal force acting on it. Weightlessness means there is no gravity. The Earth's spinning motion causes gravity. Momentum is not a vector. Conservation of momentum applies only to collisions. Momentum is the same as force. Moving masses in the absence of gravity do not have momentum. Momentum is not conserved in collisions with "immovable" objects. Momentum and kinetic energy are the same. Circular motion does not require a force. Centrifugal forces are real. An object moving in a circle with constant speed has no acceleration. An object moving in a circle will continue in circular motion when released. An object in circular motion will fly out radially when released.

Diverse Learners

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Course Content

Energy, energy transformations and energy conservation

- Energy transformation and conservation
- Energy in springs
- Work and power

Content Elaboration

Building on energy concepts developed in physical science (kinetic energy, gravitational potential energy, work, and energy conservation) and chemistry (thermal energy), the principle of conservation of energy is applied to increasingly complex situations, including those that involve spring potential energy and those that transfer energy into or out of the system as thermal energy or heat. Power is introduced as the rate at which energy is transferred. Important topics include:

- Energy transformation and conservation

Energy is always conserved. This means that 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. For physics, calculations are more complex and can involve kinetic energy, elastic potential energy, gravitational potential energy, and energy
transferred through work or heat.

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. Whenever the amount of energy in one place decreases, the amount in other places or forms increases by the same amount.

The conservation of energy principle applies to any defined system and time interval within a situation or event. 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. [Back to Energy Outline]

- **Energy in springs**

  The approximation for the change in the potential elastic energy of an elastic object (such as a spring) is \(\Delta E_{\text{elastic}} = \frac{1}{2} k \Delta x^2\) where \(\Delta x\) is the distance the elastic object is stretched or compressed from its relaxed length. [Back to Energy Outline]

- **Work and power**

  Work calculations in physical science were limited to situations in which the force and the displacement were in the same direction. In physics, work can be calculated for situations in which the force and the displacement are at angles using the equation \(W = F \Delta x \cos \theta\) where \(W\) is the work, \(F\) is the force, \(\Delta x\) is the displacement, and \(\theta\) 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 \((J/s)\). [Back to Energy Outline]

**Expectations for Learning: Cognitive Demands**

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**Design and build a mousetrap car that will travel across the floor. Test and calibrate the vehicle so that the distance it travels can be controlled. After calibrating the cars, each group will be given a different target distance for each of the cars to reach. Designs will be compared and evaluated to determine the most effective design factors.**

**Release a cart from several different positions on a ramp and let it travel to the bottom of the ramp and across the table until it slows to a stop. Investigate the relationship between the height of release and the distance it travels before stopping. From the data, determine the average friction force acting on the rolling cart. Identify the assumptions used to determine the friction force.**

**Instructional Strategies and Resources:** This section provides additional support and information for educators. These are strategies for actively engaging students with the topic and for providing hands-on minds-on observation and exploration of the topic, including authentic data resources for scientific inquiry, experimentation and problem-based tasks that incorporate technology and technological and engineering design. Resources selected are printed or web-based materials that directly relate to the particular Content Statement. It is not intended to be a prescriptive list of lessons.

"Masses and Springs" is an interactive simulation from PhET that allows students to hang masses from springs and adjust the spring stiffness, damping, and even transport the apparatus to different planets. The resulting motion can be shown in slow motion. A chart shows the kinetic, potential, and thermal energy for each spring.

This tutorial from The Physics Classroom demonstrates the strategy of using energy bar graphs to solve conservation of energy problems.
Common Misconceptions
This site lists common misconceptions for many physics topics, including those that deal with energy:  

1. Energy gets used up or runs out.  
2. Something not moving can't have any energy. 
3. A force acting on an object does work even if the object does not move.  
4. Energy is destroyed in transformations from one type to another.  
5. Energy can be recycled. 
6. Gravitational potential energy is the only type of potential energy.  
7. When an object is released to fall, the gravitational potential energy immediately becomes all kinetic energy. 
8. Energy is not related to Newton's laws. 
9. Energy is a force.

Diverse Learners

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Course Content

Waves

- Mechanical waves
  - Reflection
  - Refraction
  - Interference
- Sound phenomena
  - Resonance in strings
  - Resonance in open and closed tubes
- Light phenomena (quantitative)
  - Ray diagrams (propagation of light)
  - Snell’s Law
  - Law of Reflection (equal angles)
  - Diffraction
  - Light colors (absorption, reflection, transmission)

Content Elaboration
In interactions of energy and matter, energy often travels through matter in the form of waves. To build upon concepts taught in physical science, the measurable properties of waves (wavelength, frequency, amplitude) are used to mathematically describe the behavior of waves (resonance, index of refraction, law of reflection, single and double-slit diffraction).

The behavior of light at an interface between materials with different indices of refraction such as air and glass and air and water also are included in this topic. The laws of reflection and refraction can be used to predict the geometric path of light through thin optical elements using ray diagrams and the location and sizes of images in mirrors, thin lenses and pinholes. The interference of waves through narrow slits and prisms (simple geometries) are calculated.

As learned in physical science, when energy in a mechanical wave reaches a barrier or boundary to another material, a portion of its energy is reflected at the boundary and a portion of the energy passes into the other material, some of which may be absorbed by the material and transferred to other forms of energy, usually thermal energy, and some of which continues as a wave in the new medium. Some of the energy may also be dissipated, transformed into thermal energy or transferred out of the system due to the interaction of the system with surrounding objects, and no longer a part of the wave. The total amount of energy must remain constant.

When mechanical waves bounce off solid 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 mechanical wave travels form one material (medium) into another material in which the wave travels at a different speed, both the speed and the wavelength of the refracted wave change according to the equation $n_1 \sin \theta_1 = n_2 \sin \theta_2$. 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. When two waves traveling in the same elastic material and with displacement in the same direction (have the same sign)
meet and superimpose, the total displacement of the material is larger than the displacement of either wave (constructive interference). When the two displacements are in opposite directions (opposite signs), the total displacement of the material is less than the displacement of the largest amplitude wave (destructive interference).

Sound requires a medium and travels through space. Sound can resonate in strings, open and closed tubes. The fundamental frequency of the sound depends upon the length of the tube or string. Calculations can be done to find the fundamental frequency or length of the string or tube.

Electromagnetic waves (radiant or light energy) do not require a material (medium) to travel through. Light sources (e.g., the Sun, a light bulb) radiate energy continually from each point on the source in all directions. As energy spreads out, whether by conduction, convection, or radiation, the total amount of energy stays the same. However, since it is spread out, less can be done with it. Light demonstrates properties of waves and therefore undergoes reflection, refraction, absorption, superposition, and diffraction. The amount of energy that is absorbed into a material depends primarily on the properties of the object. For example, the visible light energy that is absorbed into opaque objects (e.g., paper, a chair, an apple) usually results in an increase in the object’s thermal energy. The light that is reflected from an opaque object is in all directions. Transparent materials transmit most of the energy through the material.

The path of light can be traced with ray diagrams. The path of light waves can be represented with ray diagrams to show reflection and refraction through lenses and mirrors. Since light is a wave, the Law of Reflection applies. In addition, light will refract when entering at an angle a different medium in which light travels at a different speed. The index of refraction of a material can be calculated by the equation $n = \frac{c}{v}$, 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. The light follows Snell's law, $n_1 \sin \theta_1 = n_2 \sin \theta_2$, in which $n$ is the index of refraction of the medium and $\theta$ is the angle the wave enters the medium, when measured from the normal line.

As light passes through a single or double slit, diffraction patterns are created with alternating lines of constructive and destructive interference.

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 continuously emitted from an object in all directions. This particle-like model is called the photon model of light energy transfer. A second model is that radiant energy travels like a mechanical wave disturbance 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, they either use the particle-like model or the wave-like model of radiant energy transfer. Students are not required to know the details of the evidence that supports either model.

Humans can only perceive visible light energy – either from a source or that which is reflected off objects – when the light interacts with the eye-brain system. Light 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 energies: from red (lowest energy) to orange, yellow, green, blue and violet (highest energy). When white light hits an object, the pigments in the object reflect one or more colors (radiant energies) in all directions and absorb the other colors (radiant energies).

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Design a system involving three refraction tanks and three different lenses so that a beam of light entering the system at a given angle can pass through all three tanks of liquid and leave the other side at a different angle.

Investigate the refraction of light as it passes from air into a new liquid medium. Draw incident and refracted rays for
many different angles and measure the angles of both. Present the material graphically to determine the index of refraction for the liquid.

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"Radio waves and electromagnetic fields" is an interactive simulation from PhET that allows students to explore how electromagnetic radiation is produced. Students can wiggle the transmitter electron manually or have it oscillate automatically and display the field as a curve or vectors. There is a strip chart that shows the electron positions at the transmitter and at the receiver.

"Geometric Optics" is an interactive simulation from PhET that illustrates how light rays are refracted by a lens. Students can adjust the focal length of the lens, move the object, move the lens, or move the screen and see how the image changes.

**Common Misconceptions**

This site lists common misconceptions for many physics topics, including these dealing with waves and light: Waves transport matter. There must be a medium for a wave to travel through. Waves do not have energy. All waves travel the same way. Frequency is connected to loudness for all amplitudes. Big waves travel faster than small waves in the same medium. Different colors of light are different types of waves. Pitch is related to intensity. Light just is and has no origin. Light is a particle. Light is a mixture of particles and waves. Light waves and radio waves are not the same thing. In refraction, the characteristics of light change. The speed of light never changes. Rays and wave fronts are the same thing. There is no interaction between light and matter. The addition of all colors of light yields black. Double slit interference shows light wave crest and troughs. Light exits in the crest of a wave and dark in the trough. In refraction, the frequency (color) of light changes. Refraction is the bending of waves.

**Diverse Learners**

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**Course Content**

**Electricity and Magnetism**

- Charging objects (friction, contact, and induction)
- Coulomb’s Law (electrostatic force between two charges)
- DC circuits
  - Ohm’s Law
  - Series circuits
  - Parallel circuits
  - Mixed circuits
  - Applying conservation of charge and energy (Kirchhoff’s Laws)
- Electric fields
- Electromagnetic Induction
- Electric generators and motors

**Content Elaboration**

The strength of the force between two charges can be calculated. How electricity is produced in a generator (electric charges in motion produce magnetic fields and a changing magnetic field creates an electric field), designing working DC circuits, using resistors, energy source, switches and light bulbs in DC circuits (both parallel and series), measuring the current and voltage in different parts of a simple series and/or parallel circuit with multiple resistors (and/or light bulbs) and Kirchoff’s Law also are included in this topic.
Increasing the voltage increases current if the resistance stays the same (use simple resistors, diodes, or LEDs; here, use of nonlinear resistors is excluded). For many materials, current is proportional to the voltage. Ohm’s Law states that the voltage is equal to the current times the resistance.

Neutral materials contain equal numbers of positive and negative charge. For all methods of charging neutral objects (e.g., rubbing together two neutral materials; charging by contact and by induction, using a van de Graaf machine or a battery), one object/system ends up with a surplus of positive charge and the other object/system ends up with the same surplus amount of negative charge. These and other experiments support the law of conservation of charge that states that charges cannot be created or destroyed. 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. 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 causes an attractive net force on the neutral conductor. 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. The polarized atoms point approximately toward the external charge. The sum of all the electrical forces on each molecule results in an attractive force for the entire insulator.

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 \[ F_e = \frac{k_e q_1 q_2}{r^2} \]. Electric forces acting within and between atoms are vastly stronger than the gravitational forces acting between the atoms. At larger scales, gravitational forces accumulate to produce a large and noticeable effect whereas electric forces tend to cancel each other out.

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, \( E = F_e / q \). 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). Electric fields can be represented by field diagrams obtained by plotting field arrows at a series of locations.

In many conducting materials, such as metals, some of the electrons are not firmly held by the nuclei of the atoms that make up the material. In these materials, applied electrical forces can cause the electrons to move through the material, producing an electric current. In insulating materials, such as glass, the electrons are held more firmly, making it nearly impossible to produce an electric current in those materials. By convention, electric current, \( I \), is the amount of positive charge that flows past a specific point each second \( (I = q / \Delta t) \). In reality, it is the negatively-charged electrons that are actually moving in a current-carrying wire. Current is the same everywhere in a circuit loop. Current is measured in amperes (A) which is equal to one coulomb of charge per second (C/s).

The potential difference, or voltage \( \Delta V \), across a battery is the potential energy difference \( \Delta E \) per unit charge \( q \) that is supplied by the energy source \( \Delta V = \Delta E / q \). Potential difference is a property of the energy source and does not depend upon the devices in the circuit. The volt (V) is the unit of potential difference and is equal to one Joule of energy per coulomb of charge (J/C). The electric potential difference across a resistor is the product of the current and the resistance \( \Delta V = I \Delta V \). 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. 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 \( P = \Delta V I \). 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 \( \Delta V_{\text{battery}} = \Delta V_1 + \Delta V_2 + \Delta V_3 + \ldots \) and \( P_{\text{battery}} = I \Delta V_1 + I \Delta V_2 + I \Delta V_3 + \ldots \).

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. Moving electrically charged objects produces magnetic forces and moving magnets produces electric forces. 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. A flow of charged particles (including an electric current in a wire) creates a magnetic field around the moving particles or the current carrying wire. Motion in a nearby magnet is evidence of this field. Calculations for the magnetic field strength are not required at this grade level. Electric currents in the earth’s interior give the earth an extensive magnetic field, which we detect from the orientation of compass needles. 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.

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 not 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 (while the magnetic field is changing). 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. Magnetic fields can be represented by field diagrams obtained by plotting field arrows at a series of locations. A changing electric field creates a magnetic field, and a changing magnetic field creates an electric field. Thus, one model of radiant energy is an electromagnetic wave in which a pattern of changing electric and magnetic fields travels at the speed of light.

**Expectations for Learning: Cognitive Demands**

This section provides definitions for Ohio’s science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science.

**Expectations for Learning: Visions into Practice**

This section provides examples of tasks that students may perform; this includes guidance for developing classroom performance tasks and assessments. It is not an all inclusive checklist of what should be done, but is a springboard for generating innovative ideas.

**Design and build a generator that will convert mechanical energy into electrical energy.**

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 series, redesign the generator.

**Use a source of constant voltage to plan and conduct an experiment to determine the relationship between the current and the resistor in a simple DC circuit.**

Analyze the results mathematically and graphically. Form a claim about the relationship between current and resistance and support the claim with evidence from your investigation.

**Instructional Strategies and Resources:** This section provides additional support and information for educators. These are strategies for actively engaging students with the topic and for providing hands-on minds-on observation and exploration of the topic, including authentic data resources for scientific inquiry, experimentation and problem-based tasks that incorporate technology and technological and engineering design. Resources selected are printed or web-based materials that directly relate to the particular Content Statement. It is not intended to be a prescriptive list of lessons.

http://phet.colorado.edu/en/simulation/circuit-construction-kit-dc This interactive simulation allows students to design and build circuits with resistors, light bulbs, batteries, and switches. Take measurements with the realistic ammeter and voltmeter. View the circuit as a schematic diagram, or switch to a life-like view.

http://phet.colorado.edu/en/simulation/battery-resistor-circuit This interactive simulation allows students to look inside a resistor to see how it works. The battery voltage can be increased to make more electrons flow through the resistor. The resistance can be increased to inhibit the flow of electrons. The current and resistor temperature change with changing voltage and resistance.

**Common Misconceptions**

This site gives common electricity and magnetism misconceptions including: A moving charge will always follow a field line as it accelerates.
If a charge is not on a field line, it feels no force. Field lines are real. Coulomb's law applies to charge systems consisting of something other than point charges. A charged body has only one type of charge. The electric field and force are the same thing and in the same direction.

Forces at a point exist without a charge there. Field lines are paths of a charges motion. The electric force is the same as the gravitational force.

Charge is continuous and can occur any amount. An electron is pure negative charge with no mass. Voltage flows through a circuit.

There is no connection between voltage and electric field. Voltage is energy. High voltage by itself is dangerous. Charges move by themselves.

Designations of (+) and (-) are absolute. Resistors consume charge. Electrons move quickly (near the speed of light) through a circuit. Charges slow down as they go through a resistor. Current is the same thing as voltage. There is no current between the terminals of a battery. The bigger the container, the larger the resistance. A circuit does not have form a closed loop for current to flow. Current gets "used up" as it flows through a circuit. A conductor has no resistance. The resistance of a parallel combination is larger than the largest resistance. Current is an excess charge. Charges that flow in circuit are from the battery. The bigger the battery, the more voltage. Power and energy are the same thing. Batteries create energy out of nothing. North and south magnetic poles are the same as positive and negative charges. Poles can be isolated.

Magnetic fields are the same as electric fields. Charges at rest can experience magnetic forces. Magnetic fields from magnets are not caused by moving charges. Generating electricity requires no work. When generating electricity only the magnet can move. Voltage can only be induced in a closed circuit. Water in dams causes electricity.

**Diverse Learners**

**Classroom Portals**

This series of videos on demand show classroom strategies for implementing inquiry into the high school classroom. While not all of the content is aligned to physical science, the strategies can be applied to any content.

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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 to promote understanding of interactions within and between systems and to explain and predict 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 can still 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.

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**Ohio’s Cognitive Demands for Science**

As with all other frameworks and cognitive demand systems Ohio’s revised 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.

These definitional paragraphs are used to describe the cognitive demand and are the prerequisite conditions that must be met, before secondary conditions are considered.

<table>
<thead>
<tr>
<th>Cognitive Demand</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Designing Technological/ Engineering Solutions Using Science Concepts (T):</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Demonstrating Science Knowledge (D):</strong></td>
<td>Requires student to use scientific inquiry 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)</td>
</tr>
<tr>
<td><strong>Interpreting and Communicating Science Concepts (C):</strong></td>
<td>Requires student to use subject specific conceptual knowledge to interpret, 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.</td>
</tr>
<tr>
<td><strong>Recalling Accurate Science (R):</strong></td>
<td>Requires students 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 task. This cognitive demand refers to students’ knowledge of science fact, information, concepts, tools, procedures, and basic principles.</td>
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*Note: Procedural knowledge (knowing how) is included in Recalling/Identifying Accurate Science.*

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Definitions for the Revised Science Standards and Model Curriculum

Strands: These are the science disciplines: Earth and space sciences, physical sciences; life science. Overlaying all the content standards and embedded in each discipline are science inquiry and applications.

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

Strand Connections: 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: The Topics 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 ODE-recommended sequence as there is no ODE-recommended sequence.

Model Curriculum: The Model Curriculum is a web-based resource that will incorporate information on “how” the material in the Content Statement may be taught. It will include Content Elaboration; Learning Expectations; and Instructional Strategies and Resources (described below).

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 what future knowledge the content will build toward.

Expectations for Learning: This section provides definitions for Ohio’s science cognitive demands which 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, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science. Ohio’s cognitive demands for science include designing technological and engineering solutions using scientific concepts, demonstrating scientific knowledge, interpreting and communicating scientific concepts and recalling accurate science.

Vision into Practice: This section provides optional examples of tasks that students may perform, these task are not mandated. It includes designing technological and engineering solutions using scientific concepts, demonstrating scientific knowledge, interpreting and communicating scientific concepts and recalling accurate science. This provides guidance for developing classroom performance tasks and assessments. These are examples not an all inclusive checklist of what should be done, but a springboard for generating innovative ideas.
Instructional Strategies and Resources: This section provides additional support and information for educators. These are strategies for actively engaging students with the topic and for providing hands-on minds-on observation and exploration of the topic, including authentic data resources for scientific inquiry, experimentation and problem-based tasks that incorporate technology and technological and engineering design. Resources selected are printed or web-based materials that directly relate to the particular Content Statement. It is not intended to be a prescriptive list of lessons. Subcategories of Instructional Strategies and Resources include:

Common Misconceptions: This section identifies misconceptions that students often have about the particular Content Statement. When available, links to resources are provided that describe the misconception and that offer suggestions for helping students overcome them.

Diverse Learners: This section will include ideas about different ways of approaching a topic to take into consideration diverse learning styles. It will contain a variety of instructional methods designed to engage all students to help them gain deep understanding of content through scientific inquiry, technology and technological and engineering design.

Classroom Portals: This section provides windows into the classroom through Webcasts, Podcasts, or video clips to exemplify and model classroom methods of teaching science using inquiry and technological design.

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