Ohio's Science Education Standards

High School Science Course Syllabi

The high school standards are organized by courses and course syllabi. The courses that were chosen meet the criteria of the Ohio Core (ORC § 3313.603 C: http://codes.ohio.gov/orc/3313.603) for science:

Beginning with students who enter ninth grade for the first time on or after July 1, 2010, except as provided in divisions (D) to (F) of this section, the requirements for graduation from every public and chartered nonpublic high school shall include twenty units that are designed to prepare students for the workforce and college. The units shall be distributed as follows:

Science, three units with inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information, which shall include the following, or their equivalent:

(a) Physical sciences, one unit;

(b) Life sciences, one unit;

(c) Advanced study in one or more of the following sciences, one unit:

(i) Chemistry, physics, or other physical science;

(ii) Advanced biology or other life science;

(iii) Astronomy, physical geology, or other earth or space science.

These are not the only courses that can be taught at the high school level, they are a sampling of courses that can be offered. The courses that would typically be introductory (grades 9 or 10) include Biology and Physical Science (a combination of Chemistry and Physics, including some Astronomy). The courses that would be considered advanced (grades 11 or 12) include: Environmental Science, Physical Geology, Chemistry, and Physics. The syllabi for the advanced science courses do not contain the same level of detail as the introductory courses. The high school courses will also have a Model Curriculum section which is where technological design, scientific inquiry and applications, and 21st century skills will be housed. All high school courses are required to be taught with inquiry and provide laboratory experiences for the students of Ohio.

Biology Course/Unit Overview and Outline

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 a 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.

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

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

Evolution
- Natural Selection and other mechanisms of biological evolution
  - Undirected variation and environmental change
  - Genetic drift, immigration, emigration and mutation
  - History of life on Earth
- Evolution and 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
  - Cellular evolution

Course Title:	Biology

Detailed Course/Unit Overview

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. 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 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 defend a scientific argument.*

Course Content
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.

Heredity

Elaboration for Instruction

Building on knowledge from elementary school (plants and animals have life cycles and offspring resemble their parents) and knowledge from middle school (reproduction, inherited traits and diversity of species), this topic focuses on the explanation of genetic mechanisms and the molecular basis of inheritance. Important concepts include:

- 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 parts of the instructions are used in different types of cells, influenced by the cell's environment and past history.
- The information passed from parents to offspring is coded in DNA molecules.
- The genetic information in DNA molecules provides instructions for assembling protein molecules. The code used is virtually the same for all life forms.
- Genes are segments of DNA molecules. Inserting, deleting or substituting DNA segments 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 as-of-yet observable effect on the offspring's success in its environment.

- Some new gene combinations make little difference, some can produce organisms with new and perhaps enhanced capabilities, and some can be deleterious.
- The sorting and recombination of genes in sexual reproduction, and meiosis specifically, result in a great variety of possible gene combinations from the offspring of any two parents.
- Gene mutations can be caused by such things as radiation and chemicals. When they occur in sex cells, the mutations can be passed on to offspring. If they occur in other cells, they can be passed on to descendant cells only. The experiences an organism has during its lifetime can affect its offspring only if the genes in its own sex cells are changed by the experience.

Evolution

Elaboration for Instruction

Building on knowledge from elementary school (living things can only survive when their basic needs are met and comparing fossils to current life forms) and from middle school (diversity of species through gradual process), this topic focuses on evolutionary mechanisms and the unity and diversity of life. Evolution is not an explanation for the origin of life, but the accepted science-based explanation for the origin of 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. This evolutionary theme can use the Modern Synthesis Theory, historical perspectives as represented by study of the theory's development from the time of Darwin and his contemporaries, deoxyribonucleic acid (DNA), phenotypic and genetic variability in populations brought about by random mutations, independent assortment and genetic recombination that occur as gametes are produced, speciation, natural selection and genetic drift. Important concepts include:

- The basic idea of biological evolution is that the Earth's present-day species developed from earlier, distinctly different species. Modern ideas about evolution provide a scientific explanation for the history of life on Earth as depicted in the fossil record and in the similarities evident within the diversity of existing species. Evolution builds on what already exists, so the more variety there is, the more there can be in the future. Evolution does not necessitate long-term progress in a set direction.
- Biological evolution accounts for the diversity of species developed through gradual processes over many generations.
- From about 4 billion years ago to about 2 billion years ago, only simple, single-celled microorganisms are found in the rock record. Once cells with nuclei developed about a billion years ago, increasingly complex multicellular organisms evolved.
- Molecular evidence substantiates the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descent branched off from one another.
- New heritable characteristics can result from new combinations of existing genes or from mutations of genes in reproductive cells. Changes in other cells of an organism cannot be passed on to the next generation. New heritable characteristics do not necessarily result in reproductive or survival advantage or disadvantage.
- There are a variety of mechanisms for evolution including but not limited to mutation, gene flow, recombination, genetic drift and natural selection. Some variation in heritable

characteristics exists within every species. Some of these characteristics give individuals an advantage over others in surviving and reproducing in particular environments. Advantaged offspring, in turn, are more likely than others to survive and reproduce. The proportion of individuals that have advantageous characteristics will increase. The continuing operation of natural selection on new characteristics and in changing environments, over and over again for millions of years, has produced a succession of diverse new species.

- Species evolve over time. Evolution is the consequence of the interactions of: (1) the potential for a species 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 ensuing selection by the environment of those offspring better able to survive and leave offspring.
- The degree of kinship between organisms or species can be estimated from the similarity of their DNA sequences, which often closely matches their classification based on anatomical similarities, patterns of development, similarity of their chemical processes and the evidence of common ancestry.
- Heritable characteristics can be observed at molecular and whole-organism levels – in structure, chemistry and/or behavior.
- Heritable characteristics influence how likely an organism is to survive and reproduce.
- When an environment and organisms that inhabit it change, the survival value of inherited characteristics may change.

Diversity and Interdependence of Life

Elaboration for Instruction

Building on knowledge from elementary school (interactions of organisms within their environment) and from middle school (cycles of matter and the flow of energy), this topic focuses on the study of diversity and similarity at the molecular level, why diversity within and among species is important, and coherence to the complex array of relationships among organisms and environments studied in prior grades.

The concept of an ecosystem should bring coherence to the complex array of relationships among organisms and environments that students have encountered. Students' growing understanding of systems in general can suggest and reinforce characteristics of ecosystems – interdependence of parts, feedback, oscillation, inputs and outputs. Variables such as population size, number and kinds of species, and productivity can be considered along with stability and change in ecosystems.

Organisms must process energy (flow of energy) and matter (cycles of matter) to survive and reproduce. The cycling of matter and flow of energy can be found at many levels of biological organization, from molecules to ecosystems. The study of food webs starts in the elementary grades with the transfer of matter, continues in the middle grades with the flow of energy through organisms, and then can be integrated in high school as students' understanding of energy storage in molecular configurations develops. Important concepts include:

- The degree of kinship between organisms or species can be estimated from the similarity of their DNA sequences, which often closely matches their classifications based on anatomical similarities.

- The great diversity of organisms is the result of more than 3.5 billion years of evolution that has filled niches with life forms.
- Disturbances in an ecosystem, such as flood, fire or the addition or loss of species, may cause the affected ecosystem to return to a system similar to its original one, or it may take a new direction, leading to a very different type of ecosystem. Climate changes can produce very large changes in an ecosystem.
- Ecosystems can be reasonably stable over hundreds or thousands of years. As any population of organisms grows, its size is limited by one or more environmental factors: availability of food; availability of nesting sites; or number of predators.
- Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution.
- The amount of life any environment can support is limited by available energy, water, oxygen and minerals, and by the ability of ecosystems to recycle the residue of dead organic materials.
- A classification system is a framework created by scientists for describing the vast diversity of organisms, indicating the degree of relatedness between organisms, and framing research questions.

Note: As food webs, food chains and interactions between organisms within ecosystems are covered in upper elementary school and middle school, they are not appropriate at this grade level.

Cells

Elaboration for Instruction

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, 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. Materials enter and leave the cell as these functions occur through a cell membrane, which serves as a boundary between the cell and its environment. Important concepts include:

- 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 and, for animal cells, movement.
- A living cell is composed of a small number of chemical 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.
- Most cells function best within a narrow range of temperature and acidity. At very low temperatures, reaction rates are too slow. High temperatures and/or extremes of acidity can irreversibly change the structure of most protein molecules. Even small changes in acidity can alter the molecules and how they interact. Both single cells and multicellular organisms have molecules that help keep the cell's acidity within a narrow range.
- Within the cell are specialized parts for the transport of materials, energy capture and release, protein building, waste disposal, information feedback and movement. In addition to these basic cellular functions common to all cells, most cells in multicellular organisms perform

some special functions that others do not.

- The work of the cell is carried out by the many different types of molecules it assembles, mostly proteins. Protein molecules are long, usually folded chains made from 20 different kinds of amino-acid molecules. The function of each protein molecule depends on its specific sequence of amino acids and the shape the chain takes.
- The genetic information in DNA molecules provides instructions for assembling protein molecules. The code used is virtually the same for all life forms.
- Cell functions are regulated. Regulation occurs through changes in the activity of the functions performed by proteins and through the selective expression of individual genes. This regulation allows cells to respond to their environments and to control and coordinate the synthesis and breakdown of specific molecules, cell growth and cell division.
- Complex interactions among the different kinds of molecules in the cell cause distinct cycles of activities, such as growth and division. Cell behavior also can be affected by molecules from other parts of the organism or other organisms.

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: Discussion of what occurs in the cell is much more important than memorizing parts of the cell.

Physical Science Course/Unit Overview and Outline

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) that requires a three-unit course with inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.

This course introduces students to key concepts and theories that provide a foundation for further study in other sciences and advanced science disciplines. Physical Science comprises the systematic study of the physical world, as related to chemistry, physics and space science.

Study of Matter

- Properties of Matter
  - Classification of Matter
    - Heterogeneous vs. homogeneous
    - Pure substances vs. mixtures
    - Compounds and elements
  - Atoms and molecules
    - Ions
    - Isotopes
- Periodic Trends of the Elements
  - Atomic structure
  - Reactivity
- Reactions of Matter
  - Bonding
  - Chemical reactions
  - Nuclear reactions

Forces, Motion and Energy

- Dynamics (cause of motion)
  - Newton's Laws
    - Constant velocity
    - Objects accelerating
    - Opposing, but equal forces – related to momentum
- Waves
  - Energy transfer and conservation
  - Behavior
    - Refraction, Reflection, Diffraction
    - Doppler shift

The Universe

- Stars
  - Formation; stages of evolution
  - Fusion in stars
- Origin of the Universe
  - Composition of Galaxies
  - Redshift
  - Theoretical Support

Course Title:	Physical Science

Detailed Course/Unit Overview

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). 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 related to chemistry, physics and space science.

Science Inquiry and Application

During the years of grades 9 through 12 all students must use the following scientific processes 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 defend a scientific argument.*

Study of Matter

Elaboration for Instruction

Building upon observation, exploration and analytical skills developed at the elementary level and middle school levels and foundational knowledge about matter (its basic particle composition and behavior under various conditions), an extensive understanding of matter, its composition and the changes it undergoes are further constructed. Substances within a closed system interact with one another in a variety of ways; however, the total mass and energy of the system remains the same. Instructional concepts include:

- Matter can be classified in different ways depending upon characteristics that are observable and characteristics that can be observed with magnification.
- Particulate nature of matter is represented by models because it is too small to see with the naked eye or with traditional visible-light microscopes.
- Atomic structure determines the properties of an element and how the 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.
- When elements are listed in order of increasing number of protons, the same sequence of properties appears over and over again. At times the masses do not correspond with periodic order, but the atomic number always does.
- Bonding describes how atoms are arranged in molecules and rearrange in chemical reactions. Atoms may be bonded together by losing, gaining or sharing electrons.
- Matter is conserved in all chemical/nonchemical analysis of mixtures. In a chemical reaction, the number, type of atoms and total mass are the same before and after the reaction.
- Radioactive substances are unstable nuclei that undergo spontaneous nuclear decay emitting particles and/or high-energy wave-like radiation.
- Nuclear fission involves the decay of large nuclei into smaller nuclei. Nuclear fusion is the joining of nuclei into a larger nucleus accompanied by the release of large quantities of energy. Nuclear

fusion in the stars creates all the elements in the universe beyond helium.

Forces, Motion and Energy

Elaboration for Instruction

Building upon the knowledge that energy is transformed and transferred all the while being conserved, an understanding of the relative strength of the forces within an atom, the nature of motion and forces and how motion is affected by forces, and wave behavior, including the Doppler effect and its applications to understanding the movement of galaxies in the universe is developed. Mathematics, including graphing, should be used when describing these phenomena, moving from qualitative understanding to one that is more quantitative. Instructional concepts include:

- Motion of an object is a measurable quantity that depends on the observer's frame of reference and is described in terms of position, speed, velocity, acceleration and time.
- 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 motion changes (speed or direction) is proportional to applied force and inversely proportional to the mass. A force is an interaction between two objects; both objects in the interaction experience an equal amount of force, but in opposite directions.
- Waves can be refracted, reflected, absorbed and superposed on one another. As waves enter a different medium, they can be reflected back into the original medium, absorbed by the new medium as energy. The waves may also be transmitted into the new medium which may result in bending the waves.
- The wavelength 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; if either is moving away, the wavelength is longer.

The Universe

Elaboration for Instruction

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:

- The stars differ from each other in size, temperature and age.
- Stars transform matter into energy in nuclear reactions. These and other processes in stars have led to the formation of all elements. The process of star formation and destruction continues.
- Early in the history of the universe, gravitational attraction caused matter to clump together to form countless trillions of stars and billions of galaxies.
- The red shift provides evidence that the universe is and has been expanding. Data from measurements of this expansion have been used in calculations that estimate the age of the universe to be over ten billion years old.

Environmental Science Syllabus

Course Title:	Environmental Science

Course/Unit Overview

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 three-unit 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.

Science Inquiry and Application

During the years of grades 9 through 12 all students must use the following scientific processes 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 defend a scientific argument.*

Course Content

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.

Historical Environmental Issues and Information

This topic explores the background and history of environmental actions and laws. This includes investigations on a local, national and global level.

- Resource use and conservation
- Environmental issues through time
  - Population changes
  - Waste management: sewage, hazardous and solid waste
  - Land use: development, zoning and agriculture (point source and non-point source contamination, thermal pollution)
  - Water: surface and ground water protection, Clean Water Act
  - Air: primary and secondary contamination, greenhouse gases, Clean Air Act
  - Industry changes, permits and regulations (point source and non-point source contamination, thermal pollution)
- Changes in Environmental Law and Regulation in the United States

Patterns and Cycles on Earth
This topic focuses on biogeochemical cycles and the connection to Earth's spheres (hydrosphere, atmosphere, biosphere and lithosphere). This includes an understanding of the cause and effect of climate change.

- Conservation of matter, physical and chemical changes that impact the environment
- Movement of matter and energy through the lithosphere, atmosphere, hydrosphere and biosphere
- Ocean and atmospheric currents, transfer of energy, global climate (including el Niño, la Niña trends)

Concepts and Principles of Environmental Science
The principles of Environmental Science include principles from other science disciplines (such as biology), but are applied to environmental issues.

- Abiotic factors that influence ecosystems
- Ecosystem equilibrium
- Energy transfer and transformation
- Climate and populations
- Evolution, natural selection, adaptation and sustainability
- Human risk factors

Global Issues
This topic adds to the historical perspective at the beginning of the course, by applying current issues and laws. Developing and using population models, collecting and analyzing water quality data, connecting to real-world, on-going issues (can be local, national or global) students will understand firsthand the issues listed below.

- Human population
- Drinking water quality and availability
- Climate change
- Deforestation
- Waste disposal (solid and hazardous)

Earth's Resources
This topic goes beyond what was part of earlier renewable and nonrenewable energy resources to learn about the effectiveness and efficiency for differing varieties at a local, state, national, and global level. In addition, Earth's resources (abiotic and biotic) as they relate to environmental issues (such as mining) are included.

- 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, groundwater, hypoxia, eutrophication)
- Soil (desertification, mass wasting, sediment contamination)

Course Title:	Chemistry

Course/Unit Overview

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 that requires a three-unit course with inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.

This course introduces students to key concepts and theories that provide a foundation for further study in other sciences as well as advanced science disciplines. Chemistry comprises a systematic study of the predictive physical interactions of matter and subsequent events that occur in the natural world. The study of matter through the exploration of classification, its structure and its interactions is how this course is organized.

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 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 defend a scientific argument.*

Course Content

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.

Classifying Matter

Elaboration for Instruction

Effective communication in science requires students to describe matter using skills which accurately quantify and qualify materials. These skills require students to master using metric prefixes, significant digits, scientific notation, standard units, derived units, error analysis, dimensional analysis, etc. In essence, students are well-versed in communicating findings using numbers to describe and distinguish specific characteristics of various materials with standardized language.

- Scientific measurement and communications
- Distinguishing characteristics of different materials

Structure of Matter

Elaboration for Instruction

The changes, and thereby reactions, that matter undergoes are directly connected to the structure of the atoms from which the matter is composed. 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. Societal implications for such changes are vast and the study thereof potentially provides students with a broader perspective in which their knowledge is applied to not only immediate experiences, but to global conditions affecting Earth and its future well-being.

- Atomic structure
  - Evolution of atomic models/theory
  - Properties of valence electrons
  - Computations based on number of subatomic particles-atomic number, atomic mass, percent abundance
- Periodic Variation
  - Electron configuration
  - Atomic size, ionization, electronegativity
  - Properties: density, melting point, phase at room temperature, conductivity
- Nuclear changes and reactions
  - Nuclear Stability
  - Nuclear equations (alpha, beta)
  - Radioactive decay
    - Unstable nucleus, nuclear force
    - Decay of nucleus (integer level half-life and characteristics of products)
    - Fission

Interactions of Matter
Elaboration for Instruction
The interactions that matter undergoes can be studied from an intramolecular perspective, as well as an intermolecular perspective (from the intramolecular perspective, students study 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. 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 them to they be diffused, while others have high *flow* capacity.

Intramolecular
- Nomenclature
- Chemical Bonding
- Chemical Reactions
  - Balancing
  - Kinetics and Equilibrium
- Stoichiometry
  - Molar calculations
  - Limiting reagents, chemical composition, empirical and molecular formula
  - Concentration of solutions
- Acids/Bases
  - Differentiation between acids and bases
  - Calculation of Hydronium and hydroxide ions
  - Identification of common acid/bases

Intermolecular
- Properties of solids, liquids and gases
- Changes of State (energy consideration of phase changes)

- Gas
- Behavior
- Laws
- Measuring

Physical Geology Syllabus

Course Title:	Physical Geology

Course/Unit Overview

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 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 defend a scientific argument.*

Course Content
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.

Part 1
Part 1 of this course begins with the building blocks of the lithosphere, minerals and rocks.

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)

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

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

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
        - Gravity, magnetism, and isostasy
        - Thermal energy (geothermal gradient and heat flow)
- Historical review (note: this would include a review of Continental Drift and Sea-Floor Spreading found in 8th grade)
    - Paleomagnetism and magnetic anomalies
    - Paleoclimatology
- Plate motion (note: introduced in 8th grade)
    - Causes and evidence of plate motion
    - Measuring plate motion
    - Characteristics of oceanic and continental plates
    - Relationship of plate movement and geologic events and features
    - Mantle plumes

Earth's resources

- Energy resources
    - Efficiency of renewable and nonrenewable energy sources
    - Resource availability
    - Extraction of resources
- Air (primary and secondary air pollution, greenhouse gases)
- Water (potable water, importance of wetlands, groundwater, hypoxia, eutrophication)
- Soil (desertification, mass wasting, sediment contamination)

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

Physics Syllabus

Course Title:	Physics

Course/Unit Overview

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 that requires a three-unit course with inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.

This course introduces students to key concepts and theories that provide a foundation for further study in science and scientific literacy. Physics is a systematic study of the predictive physical interactions of matter and subsequent events that occur in the natural world.

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 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 defend a scientific argument.*

Course Content
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.

<u>Motion in Two Dimensions and Periodic Motion</u>

Elaboration for Instruction

One-dimensional to two-dimensional motion, the ideas of displacement, velocity and acceleration that were introduced in Physical Science are developed further in this topic. Simple examples of projectile, oscillating (spring systems, pendulums), and circular motion are used to demonstrate these different types of motion.

- Vectors (two-dimensional)
- Projectile motion
- Circular motion
- Linear and two-dimensional periodic motion

<u>Forces and Two-Dimensional Motion</u>

Elaboration for Instruction

Gravitational force acts between all masses and always creates a force of attraction (introduced in Grade 8 and Physical Science). Application of Newton's Universal Law of Gravitation is used to explain how two objects that are gravitationally bound orbit a common center of mass. Incorporating spring forces (in static and cases of oscillatory motion), air resistance and friction are included in this topic. Also included are Newton's laws of motion (for objects in free fall and calculating terminal velocity when air resistance plays a significant role) and the application of Newton's laws of motion to analyze, mathematically describe and predict the effects of forces on the two-dimensional motions of objects. The effect of the gravitational force in producing a two-dimensional orbit around an object can be calculated. Newton's second law which describes the effect of forces on the motion of an object (namely balanced forces result in a constant velocity or no velocity, unbalanced forces) should be used to determine the rate of change in the velocity which is proportional to the net force applied.

Momentum is the product of the mass and the velocity of an object. Since mass is a scalar quantity and velocity is a vector quantity, momentum is a vector quantity. When objects collide, the collision can be either elastic or inelastic. For elastic collisions, both momentum and energy are conserved. For inelastic collisions, only momentum is conserved. The momentum of two objects should be calculated before and after either an elastic or inelastic collision, given the appropriate information. In this topic, one-dimensional and two-dimensional collisions are included. All components of momentum are conserved in collisions, in the absence of external forces (within a closed system).

- Newton's Laws with balanced forces
- Newton's Laws with unbalanced forces
- Momentum, conservation of momentum
- Vectors (one- and two-dimensional)

<u>Energy, energy transformations and energy conservation</u>

Elaboration for Instruction

Building on Physical Science (kinetic and gravitational potential energy), two-dimensional mathematical representations will be used for kinetic and potential energy in the context of springs, collisions or circular motion. In a closed system, energy is conserved and can be accounted for; however, in the real world, energy is transformed into unusable forms, generally as thermal energy. Energy transformations and conservation of energy will be evaluated in scenarios that include damped periodic motion, friction and production of thermal energy.

Force acting over a distance is work. Work will change the energy of a system so that when a pendulum is raised, work is done on it to raise the mass and give it gravitational potential energy. Then the pendulum can convert the gravitational potential energy to kinetic energy (motion). Power is the amount of work done in a given amount of time (work over time). Work and power are calculated in systems (e.g., springs, collisions or circular motion).

Energy transformation and conservation will be evaluated and calculated in conduction, convection and radiation (building upon Grade 7 and Physical Science). In any of these processes, the total energy is conserved. (Energy is always conserved.)

- Work and power

- Energy transformation and conservation
- Collisions
- Thermal energy production, friction
- Energy conservation under conduction, convection and radiation

<u>Interactions of energy and matter – waves</u>

Elaboration for Instruction

In interactions of energy and matter, energy often travels through matter in the form of waves. To build upon Physical Science, the measurable properties of waves (wavelength, frequency, amplitude) are used to mathematically describe properties of materials (index of refraction, reflectivity).

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.

Observed wavelength of a wave depends upon the relative motion of the source and the observer. The Doppler equation is used to determine the change in wavelength and/or frequency due to the motion of a (sound or light) source or observer.

Note: Basis of redshift has been introduced in Physical Science.

- Wave properties
    - Frequency-wavelength relationship (mathematically)
    - Index of refraction, material properties (calculating)
    - Speeds (velocities) of waves in different media (calculating)
- Light phenomena (quantitative)
    - Ray diagrams (propagation of light)
    - Snell's Law
    - Law of Reflection (equal angles)
    - Young's Experiment (diffraction)
    - Light colors (absorption, reflection, transmission)
- Doppler effect (quantitative)

<u>Electricity and Magnetism</u>

Elaboration for Instruction

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.

- Coulomb’s Law (electrostatic force between two charges)
- Induction (moving magnet through a coil produces electric field)
- Ampere’s Law (moving charge or current produces magnetic field)
- Electric generators (relative motion between a conducting coil and a magnet can produce an electric current)
- DC circuits – parallel and series
    - Basics of Kirchoff’s Law
- Properties of materials related to the electrical conduction
    - Ohm’s Law