
Science Curriculum Standards, 9-12

The Background:

State of Tennessee

Rules, Regulations and Minimum Standards for the Governance of Tennessee Public Schools (0520-1-3-.05, State Curriculum, Requirement D) states

The State Board of Education shall adopt a curriculum framework for each subject area, grades K-12. These frameworks shall contain the broad goals and objectives which identify the minimum content required at each grade level and for each course. The approved courses shall be the basis for planning instructional programs in each local school system. The established six year cycle for the selection and adoption of textbooks shall determine the order of implementation of the state curriculum framework, grades K-12. The state curriculum framework for each subject shall be distributed to local school systems at least one full school year prior to the year in which the textbooks are to be adopted.

The current science framework has been in place since 2003-2004. A revised curriculum framework for science must be implemented by school districts during the 2009-2010 school year. The Department of Education has now completed a standards revision process for 9-12 science. Approval of the new curriculum by January 2008 will enable the Tennessee Department of Education to meet the State Board requirement of having an approved set of standards for guidance with the science textbook adoption during school year 2008-2009.

The Master Plan Connection:

This item supports the State Board's Master Plan by providing a high quality science curriculum that has been developed in accordance with the national standards in science, is aligned with the National Assessment for Educational Progress 2009 Science Framework, and ACT College Readiness Benchmarks.

The Recommendation:

The Department of Education recommends adoption of the updated 9-12 science curriculum standards on final reading. The SBE staff concurs with this recommendation.

Tennessee Science Curriculum Framework

Physical Science

Course Description

Physical Science is a laboratory course that explores the relationship between matter and energy. Students explore physical science concepts through an inquiry approach integrated with appropriate algebra-based mathematics.

Students investigate:

- Inquiry
- Mathematics
- Technology and Engineering
- Energy
- Matter
- Motion
- Forces

Inquiry

Conceptual Strand

Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21st century.

Guiding Question

What tools, skills, and knowledge are needed to conduct scientific inquiry?

Course Level Expectations

CLE 3202.Inq.1 Recognize that science is a progressive endeavor that reevaluates and extends what is already accepted.

CLE 3202.Inq.2 Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.

CLE 3202.Inq.3 Use appropriate tools and technology to collect precise and accurate data.

CLE 3202.Inq.4 Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.

CLE 3202.Inq.5 Compare experimental evidence and conclusions with those drawn by others about the same testable question.

CLE 3202.Inq.6 Communicate and defend scientific findings.

Checks for Understanding (Formative/Summative Assessment)

✓3202.Inq.1 Trace the historical development of a scientific principle or theory.

- ✓3202.Inq.2 Conduct scientific investigations that include testable questions, verifiable hypotheses, and appropriate variables to explore new phenomena or verify the experimental results of others.
- ✓3202.Inq.3 Select appropriate tools and technology to collect precise and accurate quantitative and qualitative data.
- ✓3202.Inq.4 Determine if data supports or contradicts a hypothesis or conclusion.
- ✓3202.Inq.5 Compare or combine experimental evidence from two or more investigations.
- ✓3202.Inq.6 Recognize, analyze, and evaluate alternative explanations for the same set of observations.
- ✓3202.Inq.7 Analyze experimental results and identify possible sources of experimental error.
- ✓3202.Inq.8 Formulate and revise scientific explanations and models using logic and evidence.

State Performance Indicators

- SPI 3202.Inq.1 Select a description or scenario that reevaluates and/or extends a scientific finding.
- SPI 3202.Inq.2 Analyze the components of a properly designed scientific investigation.
- SPI 3202.Inq.3 Determine appropriate tools to gather precise and accurate data.
- SPI 3202.Inq.4 Evaluate the accuracy and precision of data.
- SPI 3202.Inq.5 Defend a conclusion based on scientific evidence.
- SPI 3202.Inq.6 Determine why a conclusion is free of bias.
- SPI 3202.Inq.7 Compare conclusions that offer different, but acceptable explanations for the same set of experimental data.

Embedded Technology and Engineering

Conceptual Strand

Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.

Guiding Question

How do science concepts, engineering skills, and applications of technology improve the quality of life?

Course Level Expectations

- CLE 3202.T/E.1 Explore the impact of technology on social, political, and economic systems.
- CLE 3202.T/E.2 Differentiate among elements of the engineering design cycle: design constraints, model building, testing, evaluating, modifying, and retesting.
- CLE 3202.T/E.3 Explain the relationship between the properties of a material and the use of the material in the application of a technology.
- CLE 3202.T/E.4 Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems.

Checks for Understanding (Formative/Summative Assessment)

- ✓3202.T/E.1 Select appropriate tools to conduct a scientific inquiry.
- ✓3202.T/E.2 Apply the engineering design process to construct a prototype that meets developmentally appropriate specifications.
- ✓3202.T/E.3 Explore how the unintended consequences of new technologies can impact human and non-human communities.
- ✓3202.T/E.4 Present research on current engineering technologies that contribute to improvements in our daily lives.
- ✓3202.T/E.5 Design a series of multi-view drawings that can be used by other students to construct an adaptive design and test its effectiveness.

State Performance Indicators

- SPI 3202.T/E.1 Distinguish among tools and procedures best suited to conduct a specified scientific inquiry.
- SPI 3202.T/E.2 Evaluate a protocol to determine the degree to which an engineering design process was successfully applied.
- SPI 3202.T/E.3 Evaluate the overall benefit to cost ratio of a new technology.
- SPI 3202.T/E.4 Use design principles to determine if a new technology will improve the quality of life for an intended audience.

Embedded Mathematics

Conceptual Strand

Physical science applies mathematics to investigate questions, solve problems, and communicate findings.

Guiding Question

What mathematical skills and understandings are needed to successfully investigate physical science?

Course Level Expectations

- CLE 3202.Math.1 Understand the mathematical principles behind the science of physics.
- CLE 3202.Math.2 Utilize appropriate mathematical equations and processes to solve basic physics problems.

Checks for Understanding (Formative/Summative Assessment)

- ✓3202.Math.1 Use a variety of notations appropriately (e.g. exponential, functional, square root).
- ✓3202.Math.2 Select and apply an appropriate method (e.g., mental mathematics, paper and pencil, or technology) for computing with real numbers, and evaluate the reasonableness of results.
- ✓3202.Math.3 Apply and interpret rates of change from graphical and numerical data.
- ✓3202.Math.4 Analyze graphs to describe the behavior of functions.
- ✓3202.Math.5 Interpret results of algebraic procedures.
- ✓3202.Math.6 Model real-world phenomena using functions and graphs.
- ✓3202.Math.7 Articulate and apply algebraic properties in symbolic manipulation.

- ✓3202.Math.8 Apply geometric properties, formulas, and relationships to solve real-world problems.
- ✓3202.Math.9 Make decisions about units, scales, and measurement tools that are appropriate for problem situations involving measurement.
- ✓3202.Math.10 Collect, represent, and describe linear and nonlinear data sets developed from the real world.
- ✓3202.Math.11 Make predictions from a linear data set using a line of best fit.
- ✓3202.Math.12 Interpret a data set using appropriate measures of central tendency.
- ✓3202.Math.13 Choose, construct, and analyze appropriate graphical representations for a data set.

State Performance Indicators

- SPI 3202.Math.1 Use real numbers to represent real-world applications (e.g., slope, rate of change, probability, and proportionality).
- SPI 3202.Math.2 Perform operations on algebraic expressions and informally justify the procedures chosen.
- SPI 3202.Math.3 Interpret graphs that depict real-world phenomena.
- SPI 3202.Math.4 Apply right triangle relationships including the Pythagorean Theorem and the distance formula.
- SPI 3202.Math.5 Use concepts of length, area, and volume to estimate and solve real-world problems.
- SPI 3202.Math.6 Demonstrate an understanding of rates and other derived and indirect measurements (e.g., velocity, miles per hour, revolutions per minute, cost per unit).

Standard 1 - Matter

Conceptual Strand 1

The composition and structure of matter is known, and it behaves according to principles that are generally understood.

Guiding Question 1

How does the structure of matter influence its physical and chemical behavior?

Course Level Expectations

- CLE 3202.1.1 Explore matter in terms of its physical and chemical properties.
- CLE 3202.1.2 Describe the structure and arrangement of atomic particles.
- CLE 3202.1.3 Characterize and classify elements based on their atomic structure.
- CLE 3202.1.4 Investigate chemical and physical changes.
- CLE 3202.1.5 Evaluate pure substances and mixtures.
- CLE 3202.1.6 Distinguish between common ionic and covalent compounds.
- CLE 3202.1.7 Construct chemical formulas for common compounds.
- CLE 3202.1.8 Investigate relationships among the pressure, temperature, and volume of gases and liquids.
- CLE 3202.1.9 Apply the Laws of Conservation of Mass/Energy to balance chemical equations.

CLE 3202.1.10 Distinguish among acids, bases, and neutral substances.

Checks for Understanding (Formative/Summative Assessment)

- ✓3202.1.1 Distinguish among solids, liquids, gases, and plasmas.
- ✓3202.1.2 Describe and illustrate the physical differences among solids, liquids, and gases in terms of their mass, volume, density, shape, and particle arrangement.
- ✓3202.1.3 Use appropriate units to measure or calculate the mass and volume of substances.
- ✓3202.1.4 Calculate the density of substances or objects.
- ✓3202.1.5 Construct and interpret a density column.
- ✓3202.1.6 Identify substances as homogeneous or heterogeneous mixtures.
- ✓3202.1.7 Construct an experiment to separate the components of a mixture.
- ✓3202.1.8 List the three major subatomic particles and distinguish among their location, charges, and relative masses.
- ✓3202.1.9 Distinguish between atomic number and atomic mass.
- ✓3202.1.10 Define an isotope and describe the use of common isotopes.
- ✓3202.1.11 Identify the number of protons, neutrons, and electrons in an atom of an isotope based on its atomic number and atomic mass.
- ✓3202.1.12 Know the chemical symbols for the common elements.
- ✓3202.1.13 Use the periodic table to determine the number of protons, neutrons, and electrons in an isotope of an element.
- ✓3202.1.14 Use the periodic table to identify the characteristics and properties of metals, non-metals, and metalloids.
- ✓3202.1.15 Label a periodic table with oxidation numbers of main group elements, identify elements likely to form ions and use information to construct formulas for compounds.
- ✓3202.1.16 Classify a substance as an element or compound based on its chemical formula or symbol.
- ✓3202.1.17 Explain ionic and covalent bonding based on the oxidation numbers of the elements in a compound.
- ✓3202.1.18 Investigate physical and chemical changes in a laboratory setting.
- ✓3202.1.19 Balance simple chemical equations, identifying the reactants, products, and proper coefficients.
- ✓3202.1.20 Predict the products of common chemical reactions.
- ✓3202.1.21 Use models to represent chemical reactions as synthesis, decomposition, single-replacement, and double-replacement.
- ✓3202.1.22 Describe synthesis, decomposition, single-replacement, and double-replacement reactions using equations.
- ✓3202.1.23 Describe how chemical symbols and balanced chemical equations illustrate the Law of Conservation of Mass/Energy.
- ✓3202.1.24 Observe and measure temperature changes to distinguish between endothermic and exothermic reactions.
- ✓3202.1.25 Conduct, analyze, and communicate the results of an experiment that demonstrates the relationship between pressure and volume of a gas.
- ✓3202.1.26 Conduct, analyze, and communicate the results of an experiment that demonstrates the relationship between temperature and volume of a gas.

- ✓3202.1.27 Apply indicators and instruments to classify a material as acidic, basic, or neutral.
- ✓3202.1.28 Conduct research on issues associated with acid rain.

State Performance Indicators

- SPI 3202.1.1 Distinguish among states of matter in terms of energy, volume, shape, particle arrangement, and phase changes.
- SPI 3202.1.2 Name, measure, and describe the physical properties of substances.
- SPI 3202.1.3 Compare different types of mixtures.
- SPI 3202.1.4 Distinguish between examples of common elements and compounds.
- SPI 3202.1.5 Compare the properties of metals, metalloids, and nonmetals.
- SPI 3202.1.6 Determine the composition of an atom and the characteristics of its subatomic particles.
- SPI 3202.1.7 Explain the interrelationship between pressure, temperature, and volume of gases.
- SPI 3202.1.8 Distinguish between physical and chemical changes in matter.
- SPI 3202.1.9 Use information about an element's position in the periodic table to determine the charge of its ions.
- SPI 3202.1.10 Classify chemical bonds in a compound as ionic or covalent.
- SPI 3202.1.11 Construct the chemical formula of a compound using the periodic table.
- SPI 3202.1.12 Identify the reactants and products in a chemical equation, and balance equations using proper coefficients.
- SPI 3202.1.13 Predict the products of common chemical reactions, given the reactants.
- SPI 3202.1.14 Distinguish among synthesis, decomposition, single-replacement, double-replacement, and combustion reactions.
- SPI 3202.1.15 Explain the Law of Conservation of Mass/Energy in terms of a balanced chemical equation.
- SPI 3202.1.16 Distinguish between endothermic and exothermic reactions.
- SPI 3202.1.17 Identify a substance as acidic, basic, or neutral based on its pH or response to an indicator or instrument.
- SPI 3202.1.18 Recognize the effect of acid rain on the environment.

Strand 2 – Energy

Conceptual Strand 2

Various forms of energy are constantly being transformed into other types without any net loss of energy from the system.

Guiding Question 2

What basic energy related ideas are essential for understanding the dependency of the natural and man-made worlds on energy?

Course Level Expectations

- CLE 3202.2.1 Investigate the properties and behaviors of mechanical and electromagnetic waves.
- CLE 3202.2.2 Explore and explain the nature of sound and light energy.
- CLE 3202.2.3 Examine the applications and effects of heat energy.
- CLE 3202.2.4 Probe the fundamental principles and applications of electricity.
- CLE 3202.2.5 Distinguish between nuclear fission and nuclear fusion.
- CLE 3202.2.6 Investigate the Law of Conservation of Energy.

Checks for Understanding (Formative/Summative Assessment)

- ✓3202.2.1 Investigate energy transfer through waves and particles.
- ✓3202.2.2 Demonstrate how waves are produced and transmitted.
- ✓3202.2.3 Investigate the characteristics of light energy and sound energy.
- ✓3202.2.4 Compare and contrast the four types of wave interactions.
- ✓3202.2.5 Explore heat as a form of energy that may be transferred between materials.
- ✓3202.2.6 Identify the boiling and freezing points of water in the Celsius, Fahrenheit, and Kelvin temperature scales.
- ✓3202.2.7 Design and conduct an activity to demonstrate the conservation of heat energy during temperature changes.
- ✓3202.2.8 Investigate the relationships among kinetic, potential, and total energy within a closed system.
- ✓3202.2.9 Solve problems related to voltage, resistance, and current in a series circuit.
- ✓3202.2.10 Investigate Ohm's law to design and build a simple circuit.
- ✓3202.2.11 Research the importance of energy conservation.
- ✓3202.2.12 Explore nuclear energy and its impact on science and society.

State Performance Indicators

- SPI 3202.2.1 Classify waves as transverse or longitudinal.
- SPI 3202.2.2 Distinguish between mechanical and electromagnetic waves.
- SPI 3202.2.3 Distinguish between wavelength, frequency, and amplitude.
- SPI 3202.2.4 Identify the boiling and freezing points of water using Celsius, Fahrenheit, or Kelvin scales.
- SPI 3202.2.5 Compare and contrast sound and light waves.
- SPI 3202.2.6 Distinguish among wave reflection, refraction, diffraction, and interference.
- SPI 3202.2.7 Classify heat transfer as conduction, convection, or radiation.
- SPI 3202.2.8 Identify a scenario that illustrates the Law of Conservation of Energy.
- SPI 3202.2.9 Solve application problems related to voltage, resistance, and current in a series circuit ($V=IR$).
- SPI 3202.2.10 Distinguish between nuclear fission and nuclear fusion.
- SPI 3202.2.11 Solve problems regarding heat, mass, specific heat capacity, and temperature change ($Q=mC\Delta T$).

Standard 3 – Motion

Conceptual Strand 3

Objects move in ways that can be observed, described, predicted, and measured.

Guiding Question 3

What causes objects to move differently under different circumstances?

Course Level Expectations

CLE 3202.3.1 Investigate the relationships among speed, position, time, velocity, and acceleration.

CLE 3202.3.2 Investigate and apply Newton's three laws of motion.

CLE 3202.3.3 Examine the Law of Conservation of Momentum in real world situations.

Checks for Understanding (Formative/Summative Assessment)

✓3202.3.1 Demonstrate the relationship between speed and velocity.

✓3202.3.2 Create models that represent Newton's three laws of motion.

✓3202.3.3 Evaluate scenarios that illustrate Newton's three laws of motion.

✓3202.3.4 Investigate the Law of Conservation of Momentum.

✓3202.3.5 Research the historical development of the laws of motion.

✓3202.3.6 Collect data to construct, analyze, and interpret graphs for experiments that involve distance, speed, velocity, and time.

✓3202.3.7 Solve problems related to velocity, acceleration, force, work, and power.

State Performance Indicators

SPI 3202.3.1 Distinguish between speed and velocity.

SPI 3202.3.2 Relate inertia, force, or action-reaction forces to Newton's three laws of motion.

SPI 3202.3.3 Distinguish among the concepts inherent in Newton's three laws of motion.

SPI 3202.3.4 Interpret a position-time graph for velocity or a velocity-time graph for acceleration.

SPI 3202.3.5 Solve application problems related to velocity, acceleration, force, work, and power using appropriate units of measurement ($v=d/t$, $a=\Delta v/t$, $F=ma$, $W=Fd$, and $P=W/t$).

SPI 3202.3.6 Choose a correct representation of the Law of Conservation of Momentum.

Standard 4 - Forces in Nature

Conceptual Strand 4

Everything in the universe exerts a gravitational force on everything else; there is interplay between magnetic fields and electrical currents.

Guiding Question 4

What are the scientific principles that explain gravity and electromagnetism?

Course Level Expectations

CLE 3202.4.1 Explore the difference between mass and weight.

CLE 3202.4.2 Relate gravitational force to mass.

CLE 3202.4.3 Demonstrate the relationships among work, power, and machines.

Checks for Understanding (Formative/Summative Assessment)

✓3202.4.1 Demonstrate the effect of gravity on objects.

✓3202.4.2 Explore the difference between mass and weight.

✓3202.4.3 Design, demonstrate, and explain simple and compound machines.

✓3202.4.4 Gather and analyze data and solve problems related to mechanical advantage and efficiency of simple machines.

State Performance Indicators

SPI 3202.4.1 Distinguish between mass and weight using SI units.

SPI 3202.4.2 Identify the effects of gravitational force on a falling body or satellite.

SPI 3202.4.3 Identify various types of simple machines.

SPI 3202.4.4 Recognize the simple machines found in a compound machine.

SPI 3202.4.5 Solve application problems related to mechanical advantage and the efficiency of simple machines, given appropriate equations ($MA = FO/FI$ and $Eff = WO/WI$).

Tennessee Science Curriculum Framework

Biology I

Course Description

Biology I is a laboratory course that investigates the relationship between structure and function from molecules to organisms and systems, the interdependence and interactions of biotic and abiotic components of the environment, and mechanisms that maintain continuity and lead to changes over time. Students explore biological concepts through an inquiry approach.

Biology I students investigate:

- Inquiry
- Technology and Engineering
- Cells
- Interdependence
- Flow of Matter and Energy
- Heredity
- Biodiversity and Change

Embedded Inquiry

Conceptual Strand

Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21st century.

Guiding Question

What tools, skills, knowledge, and dispositions are needed to conduct scientific inquiry?

Course Level Expectations

CLE 3210.Inq.1 Recognize that science is a progressive endeavor that reevaluates and extends what is already accepted.

CLE 3210.Inq.2 Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.

CLE 3210.Inq.3 Use appropriate tools and technology to collect precise and accurate data.

CLE 3210.Inq.4 Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.

CLE 3210.Inq.5 Compare experimental evidence and conclusions with those drawn by others about the same testable question.

CLE 3210.Inq.6 Communicate and defend scientific findings.

Checks for Understanding (Formative/Summative Assessment)

- ✓3210.Inq.1 Trace the historical development of a scientific principle or theory, such as cell theory, evolution, or DNA structure.
- ✓3210.Inq.2 Conduct scientific investigations that include testable questions, verifiable hypotheses, and appropriate variables to explore new phenomena or verify the experimental results of others.
- ✓3210.Inq.3 Select appropriate tools and technology to collect precise and accurate quantitative and qualitative data.
- ✓3210.Inq.4 Determine if data supports or contradicts a hypothesis or conclusion.
- ✓3210.Inq.5 Compare or combine experimental evidence from two or more investigations.
- ✓3210.Inq.6 Recognize, analyze, and evaluate alternative explanations for the same set of observations.
- ✓3210.Inq.7 Analyze experimental results and identify possible sources of experimental error.
- ✓3210.Inq.8 Formulate and revise scientific explanations and models using logic and evidence.

State Performance Indicators

- SPI 3210 Inq.1 Select a description or scenario that reevaluates and/or extends a scientific finding.
- SPI 3210 Inq.2 Analyze the components of a properly designed scientific investigation.
- SPI 3210 Inq.3 Determine appropriate tools to gather precise and accurate data.
- SPI 3210 Inq.4 Evaluate the accuracy and precision of data.
- SPI 3210 Inq.5 Defend a conclusion based on scientific evidence.
- SPI 3210 Inq.6 Determine why a conclusion is free of bias.
- SPI 3210 Inq.7 Compare conclusions that offer different, but acceptable explanations for the same set of experimental data.

Embedded Technology and Engineering

Conceptual Strand

Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.

Guiding Question

How do science concepts, engineering skills, and applications of technology improve the quality of life?

Course Level Expectations

- CLE 3210.T/E.1 Explore the impact of technology on social, political, and economic systems.
- CLE 3210.T/E.2 Differentiate among elements of the engineering design cycle: design constraints, model building, testing, evaluating, modifying, and retesting.
- CLE 3210.T/E.3 Explain the relationship between the properties of a material and the use of the material in the application of a technology.

CLE 3210.T/E.4 Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems.

Checks for Understanding (Formative/Summative Assessment)

- ✓3210.T/E.1 Select appropriate tools to conduct a scientific inquiry.
- ✓3210.T/E.2 Apply the engineering design process to construct a prototype that meets developmentally appropriate specifications.
- ✓3210.T/E.3 Explore how the unintended consequences of new technologies can impact human and non-human communities.
- ✓3210.T/E.4 Present research on current bioengineering technologies that advance health and contribute to improvements in our daily lives.
- ✓3210.T/E.5 Design a series of multi-view drawings that can be used by other students to construct an adaptive design and test its effectiveness.

State Performance Indicators

- SPI 3210.T/E.1 Distinguish among tools and procedures best suited to conduct a specified scientific inquiry.
- SPI 3210.T/E.2 Evaluate a protocol to determine the degree to which an engineering design process was successfully applied.
- SPI 3210.T/E.3 Evaluate the overall benefit to cost ratio of a new technology.
- SPI 3210.T/E.4 Use design principles to determine if a new technology will improve the quality of life for an intended audience.

Embedded Mathematics

Conceptual Strand

Science applies mathematics to investigate questions, solve problems, and communicate findings.

Guiding Question

What mathematical skills and understandings are needed to successfully investigate biological topics?

Course Level Expectations

- CLE 3210.Math.1 Understand the mathematical principles associated with the science of biology.
- CLE 3210.Math.2 Utilize appropriate mathematical equations and processes to understand biological concepts.

Checks for Understanding (Formative/Summative Assessment)

- ✓3210.Math.1 Choose and construct appropriate graphical representations for a data set.
- ✓3210.Math.2 Analyze graphs to interpret biological events.
- ✓3210.Math.3 Make decisions about units, scales, and measurement tools that are appropriate for investigations involving measurement.
- ✓3210.Math.4 Select and apply an appropriate method to evaluate the reasonableness of results.

- ✓3210.Math.5 Apply and interpret rates of change from graphical and numerical data.
- ✓3210.Math.6 Apply probabilistic reasoning to solve genetic problems.

State Performance Indicators

- SPI 3210.Math.1 Interpret a graph that depicts a biological phenomenon.
- SPI 3210.Math.2 Predict the outcome of a cross between parents of known genotype.

Standard 1 – Cells

Conceptual Strand 1

All living things are made of cells that perform functions necessary for life.

Guiding Question 1

How are cells organized to carry on the processes of life?

Course Level Expectations

- CLE 3210.1.1 Compare the structure and function of cellular organelles in both prokaryotic and eukaryotic cells.
- CLE 3210.1.2 Distinguish among the structure and function of the four major organic macromolecules found in living things.
- CLE 3210.1.3 Describe how enzymes regulate chemical reactions in the body.
- CLE 3210.1.4 Describe the processes of cell growth and reproduction.
- CLE 3210.1.5 Compare different models to explain the movement of materials into and out of cells.

Checks for Understanding (Formative/Summative Assessment)

- ✓3210.1.1 Investigate cells using a compound microscope.
- ✓3210.1.2 Construct a model of a prokaryotic or eukaryotic cell.
- ✓3210.1.3 Design a graphic organizer that compares proteins, carbohydrates, lipids, and nucleic acids.
- ✓3210.1.4 Conduct tests to detect the presence of proteins, carbohydrates, and lipids.
- ✓3210.1.5 Design a model that illustrates enzyme function.
- ✓3210.1.6 Demonstrate the movement of chromosomes during mitosis in plant and animal cells.
- ✓3210.1.7 Design and conduct an experiment to investigate the effect of various solute concentrations on water movement in cells.
- ✓3210.1.8 Analyze experimental data to distinguish between active and passive transport.

State Performance Indicators

- SPI 3210.1.1 Identify the cellular organelles associated with major cell processes.
- SPI 3210.1.2 Distinguish between prokaryotic and eukaryotic cells.
- SPI 3210.1.3 Distinguish among proteins, carbohydrates, lipids, and nucleic acids.
- SPI 3210.1.4 Identify positive tests for carbohydrates, lipids, and proteins.
- SPI 3210.1.5 Identify how enzymes control chemical reactions in the body.
- SPI 3210.1.6 Determine the relationship between cell growth and cell reproduction.

SPI 3210.1.7 Predict the movement of water and other molecules across selectively permeable membranes.

SPI 3210.1.8 Compare and contrast active and passive transport.

Standard 2 – Interdependence

Conceptual Strand 2

All life is interdependent and interacts with the environment.

Guiding Question 2

How do living things interact with one another and with the non-living elements of their environment?

Course Level Expectations

CLE 3210.2.1 Investigate how the dynamic equilibrium of an ecological community is associated with interactions among its organisms.

CLE 3210.2.2 Analyze and interpret population data, graphs, or diagrams.

CLE 3210.2.3 Predict how global climate change, human activity, geologic events, and the introduction of non-native species impact an ecosystem.

CLE 3210.2.4 Describe the sequence of events associated with biological succession.

Checks for Understanding (Formative/Summative Assessment)

✓3210.2.1 Analyze human population distribution graphs to predict the impact on global resources, society, and the economy.

✓3210.2.2 Construct and maintain a model of an ecosystem.

✓3210.2.3 Monitor and evaluate changes in a yeast population.

✓3210.2.4 Investigate an outdoor habitat to identify the abiotic and biotic factors, plant and animal populations, producers, consumers, and decomposers.

✓3210.2.5 Conduct research on how human influences have changed an ecosystem and communicate findings through written or oral presentations.

✓3210.2.6 Describe a sequence of events that illustrates biological succession.

State Performance Indicators

SPI 3210.2.1 Predict how population changes of organisms at different trophic levels affect an ecosystem.

SPI 3210.2.2 Interpret the relationship between environmental factors and fluctuations in population size.

SPI 3210.2.3 Determine how the carrying capacity of an ecosystem is affected by interactions among organisms.

SPI 3210.2.4 Predict how various types of human activities affect the environment.

SPI 3210.2.5 Make inferences about how a specific environmental change can affect the amount of biodiversity.

SPI 3210.2.6 Predict how a specific environmental change may lead to the extinction of a particular species.

SPI 3210.2.7 Analyze factors responsible for the changes associated with biological succession.

Standard 3 – Flow of Matter and Energy

Conceptual Strand 3

Matter cycles and energy flows through the biosphere.

Guiding Question 3

What are the scientific explanations for how matter cycles and energy flows through the biosphere?

Course Level Expectations

CLE 3210.3.1 Analyze energy flow through an ecosystem.

CLE 3210.3.2 Distinguish between aerobic and anaerobic respiration.

CLE 3210.3.3 Investigate the relationship between the processes of photosynthesis and cellular respiration.

CLE 3210.3.4 Describe the events which occur during the major biogeochemical cycles.

Check for Understanding (Formative/Summative Assessment)

✓3210.3.1 Track energy flow through an ecosystem.

✓3210.3.2 Construct a concept map to differentiate between aerobic and anaerobic respiration.

✓3210.3.3 Conduct experiments to investigate photosynthesis and cellular respiration.

✓3210.3.4 Investigate the process of fermentation.

✓3210.3.5 Construct models of the carbon, oxygen, nitrogen, phosphorous, and water cycles.

State Performance Indicators

SPI 3210.3.1 Interpret a diagram that illustrates energy flow in an ecosystem.

SPI 3210.3.2 Distinguish between aerobic and anaerobic respiration.

SPI 3210.3.3 Compare and contrast photosynthesis and cellular respiration in terms of energy transformation.

SPI 3210.3.4 Predict how changes in a biogeochemical cycle can affect an ecosystem.

Standard 4 – Heredity

Conceptual Strand 4

Organisms reproduce and transmit hereditary information.

Guiding Question 4

What are the principal mechanisms by which living things reproduce and transmit hereditary information from parents to offspring?

Course Level Expectations

CLE 3210.4.1 Investigate how genetic information is encoded in nucleic acids.

CLE 3210.4.2 Describe the relationships among genes, chromosomes, proteins, and hereditary traits.

CLE 3210.4.3 Predict the outcome of monohybrid and dihybrid crosses.

- CLE 3210.4.4 Compare different modes of inheritance: sex linkage, co-dominance, incomplete dominance, multiple alleles, and polygenic traits.
- CLE 3210.4.5 Recognize how meiosis and sexual reproduction contribute to genetic variation in a population.
- CLE 3210.4.6 Describe the connection between mutations and human genetic disorders.
- CLE 3210.4.7 Assess the scientific and ethical ramifications of emerging genetic technologies.

Checks for Understanding (Formative/Summative Assessment)

- ✓3210.4.1 Use models of DNA, RNA, and amino acids to explain replication and protein synthesis.
- ✓3210.4.2 Complete and interpret genetic problems that illustrate sex linkage, co-dominance, incomplete dominance, multiple alleles, and polygenic inheritance.
- ✓3210.4.3 Apply data to complete and interpret a genetic pedigree.
- ✓3210.4.4 Describe how the process of meiosis controls the number of chromosomes in a gamete.
- ✓3210.4.5 Associate gene mutation with changes in a DNA molecule.
- ✓3210.4.6 Design an informational brochure to describe a human genetic disorder.
- ✓3210.4.7 Conduct research to explore the scientific and ethical issues associated with emerging gene technologies.

State Performance Indicators

- SPI 3210.4.1 Identify the structure and function of DNA.
- SPI 3210.4.2 Associate the process of DNA replication with its biological significance.
- SPI 3210.4.3 Recognize the interactions between DNA and RNA during protein synthesis.
- SPI 3210.4.4 Determine the probability of a particular trait in an offspring based on the genotype of the parents and the particular mode of inheritance.
- SPI 3210.4.5 Apply pedigree data to interpret various modes of genetic inheritance.
- SPI 3210.4.6 Describe how meiosis is involved in the production of egg and sperm cells.
- SPI 3210.4.7 Describe how meiosis and sexual reproduction contribute to genetic variation in a population.
- SPI 3210.4.8 Determine the relationship between mutations and human genetic disorders.
- SPI 3210.4.9 Evaluate the scientific and ethical issues associated with gene technologies: genetic engineering, cloning, transgenic organism production, stem cell research, and DNA fingerprinting.

Standard 5 – Biodiversity and Change

Conceptual Strand 5

A rich variety and complexity of organisms have developed in response to changes in the environment.

Guiding Question 5

How does natural selection explain how organisms have changed over time?

Course Level Expectations

- CLE 3210.5.1 Associate structural, functional, and behavioral adaptations with the ability of organisms to survive under various environmental conditions.
- CLE 3210.5.2 Analyze the relationship between form and function in living things.
- CLE 3210.5.3 Explain how genetic variation in a population and changing environmental conditions are associated with adaptation and the emergence of new species.
- CLE 3210.5.4 Summarize the supporting evidence for the theory of evolution.
- CLE 3210.5.5 Explain how evolution contributes to the amount of biodiversity.
- CLE 3210.5.6 Explore the evolutionary basis of modern classification systems.

Checks for Understanding (Formative/Summative Assessment)

- ✓3210.5.1 Create graphic organizers to demonstrate the relationship between form and function in representative organisms.
- ✓3210.5.2 Explain how natural selection operates in the development of a new species.
- ✓3210.5.3 Associate fossil data with biological and geological changes in the environment.
- ✓3210.5.4 Analyze a variety of models, samples, or diagrams to demonstrate the genetic relatedness of organisms.
- ✓3210.5.5 Use a dichotomous key to identify an unknown organism.

State Performance Indicators

- SPI 3210.5.1 Compare and contrast the structural, functional, and behavioral adaptations of animals or plants found in different environments.
- SPI 3210.5.2 Recognize the relationship between form and function in living things.
- SPI 3210.5.3 Recognize the relationships among environmental change, genetic variation, natural selection, and the emergence of a new species.
- SPI 3210.5.4 Describe the relationship between the amount of biodiversity and the ability of a population to adapt to a changing environment.
- SPI 3210.5.5 Apply evidence from the fossil record, comparative anatomy, amino acid sequences, and DNA structure that support modern classification systems.
- SPI 3210.5.6 Infer relatedness among different organisms using modern classification systems.

Tennessee Science Curriculum Framework

Conceptual Physics

Course Description

Conceptual Physics is a laboratory course that examines the interactions between matter and energy. Students explore physics concepts through an inquiry approach integrated with appropriate algebra-based mathematics.

Conceptual Physics students investigate:

- Inquiry
- Technology and Engineering
- Mathematics
- Mechanics
- Thermodynamics
- Waves and Optics
- Electricity and Magnetism
- Nuclear Science

Embedded Inquiry

Conceptual Strand

Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21st century.

Guiding Question

What tools, skills, knowledge, and dispositions are needed to conduct scientific inquiry?

Course Level Expectations

CLE 3200.Inq.1 Recognize that science is a progressive endeavor that reevaluates and extends what is already accepted.

CLE 3200.Inq.2 Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.

CLE 3200.Inq.3 Use appropriate tools and technology to collect precise and accurate data.

CLE 3200.Inq.4 Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.

CLE 3200.Inq.5 Compare experimental evidence and conclusions with those drawn by others about the same testable question.

CLE 3200.Inq.6 Communicate and defend scientific findings.

Checks for Understanding (Formative/Summative Assessment)

- ✓ 3200.Inq.1 Develop a testable question for a scientific investigation.
- ✓ 3200.Inq.2 Develop an experimental design for testing a hypothesis.
- ✓ 3200.Inq.3 Select appropriate independent, dependent, or controlled variables for an experiment.
- ✓ 3200.Inq.4 Perform an experiment to test a prediction.
- ✓ 3200.Inq.5 Gather, organize, and transform data from an experiment into a table, graph, or diagram.
- ✓ 3200.Inq.6 Analyze data from a table, graph, or diagram.
- ✓ 3200.Inq.7 Analyze and interpret the results of an experiment.
- ✓ 3200.Inq.8 Apply knowledge and data-interpretation skills to support a conclusion.
- ✓ 3200.Inq.9 Determine whether data supports or contradicts a simple hypothesis or conclusion.
- ✓ 3200.Inq.10 Analyze experimental results and identify possible sources of experimental error.
- ✓ 3200.Inq.11 State a conclusion in terms of the relationship between two or more variables.
- ✓ 3200.Inq.12 Compare the results of an experiment with what is already known about the topic under investigation.
- ✓ 3200.Inq.13 Suggest alternative explanations for the same set of observations.
- ✓ 3200.Inq.14 Formulate and revise scientific explanations and models using logic and evidence.

Embedded Technology and Engineering

Conceptual Strand

Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.

Guiding Question

How do science concepts, engineering skills, and applications of technology improve the quality of life?

Course Level Expectations

- CLE 3200.T/E.1 Explore the impact of technology on social, political, and economic systems.
- CLE 3200.T/E.2 Differentiate among elements of the engineering design cycle: design constraints, model building, testing, evaluating, modifying, and retesting.
- CLE 3200.T/E.3 Explain the relationship between the properties of a material and the use of the material in the application of a technology.
- CLE 3200.T/E.4 Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems.

Checks for Understanding (Formative/Summative Assessment)

- ✓ 3200.T/E.1 Select appropriate tools to conduct a scientific inquiry.
- ✓ 3200.T/E.2 Apply the engineering design process to construct a prototype that meets developmentally appropriate specifications.

- ✓3200.T/E.3 Explore how the unintended consequences of new technologies can impact human and non-human communities.
- ✓3200.T/E.4 Present research on current engineering technologies that contribute to improvements in our daily lives.
- ✓3200.T/E.5 Design a series of multi-view drawings that can be used by other students to construct an adaptive design and test its effectiveness.

Embedded Mathematics

Conceptual Strand

Physics applies mathematics to investigate questions, solve problems, and communicate findings.

Guiding Question

What mathematical skills and understandings are needed to successfully investigate conceptual physics?

Course Level Expectations

- CLE 3200.Math.1 Understand the mathematical principles that underlie the science of physics.
- CLE 3200.Math.2 Utilize appropriate mathematical equations and processes to solve basic physics problems.

Checks for Understanding (Formative/Summative Assessment)

- ✓3200.Math.1 Use a variety of notations appropriately (e.g., exponential, functional, square root).
- ✓3200.Math.2 Select and apply an appropriate method for computing with real numbers, and evaluate the reasonableness of results.
- ✓3200.Math.3 Apply and interpret rates of change from graphical and numerical data.
- ✓3200.Math.4 Analyze graphs to describe the behavior of functions.
- ✓3200.Math.5 Interpret results of algebraic procedures.
- ✓3200.Math.6 Model real-world phenomena using functions and graphs.
- ✓3200.Math.7 Articulate and apply algebraic properties in symbolic manipulation.
- ✓3200.Math.8 Apply and communicate measurement concepts and relationships in algebraic and geometric problem-solving situations.
- ✓3200.Math.9 Make decisions about units, scales, and measurement tools that are appropriate for problem situations involving measurement.
- ✓3200.Math.10 Collect, represent, and describe linear and nonlinear data sets developed from the real world.
- ✓3200.Math.11 Make predictions from a linear data set using a line of best fit.
- ✓3200.Math.12 Interpret a data set using appropriate measures of central tendency.
- ✓3200.Math.13 Choose, construct, and analyze appropriate graphical representations for a data set.
- ✓3200.Math.14 Use real numbers to represent real-world applications (e.g., slope, rate of change, probability, and proportionality).

- ✓3200.Math.15 Apply right triangle relationships including the Pythagorean Theorem and the distance formula.
- ✓3200.Math.16 Use concepts of length, area, and volume to estimate and solve real-world problems.
- ✓3200.Math.17 Demonstrate an understanding of rates and other derived and indirect measurements (e.g., velocity, miles per hour, revolutions per minute, and cost per unit).

Standard 1 – Mechanics

Conceptual Strand 1

The laws and properties of mechanics provide the foundations of Conceptual Physics.

Guiding Question 1

How do the laws and properties of mechanics govern the basic understanding of physics concepts?

Course Level Expectations

- CLE 3200.1.1 Investigate fundamental physical quantities of mass and time.
- CLE 3200.1.2 Analyze and apply Newton’s three laws of motion.
- CLE 3200.1.3 Differentiate among work, energy, and power.
- CLE 3200.1.4 Investigate kinematics and dynamics.
- CLE 3200.1.5 Investigate and apply Archimedes’s Principle.
- CLE 3200.1.6 Explore Pascal’s Principle.
- CLE 3200.1.7 Analyze applications of Bernoulli’s Principle.

Checks for Understanding (Formative/Summative Assessment)

- ✓ 3200.1.1 Investigate, measure, and calculate position, displacement, velocity and acceleration.
- ✓ 3200.1.2 Analyze vector diagrams.
- ✓ 3200.1.3 Explore characteristics of rectilinear motion and create distance-time graphs and velocity-time graphs.
- ✓ 3200.1.4 Investigate the characteristics of centripetal motion and centripetal acceleration.
- ✓ 3200.1.5 Evaluate the dynamics of systems in motion and collisions including friction, gravity, impulse and momentum, change in momentum and conservation of momentum.
- ✓ 3200.1.6 Investigate projectile motion.
- ✓ 3200.1.7 Distinguish between mass and weight using SI units.
- ✓ 3200.1.8 Measure and calculate mechanical advantage of mechanical devices.
- ✓ 3200.1.9 Relate time to the independent variable of most experiments.
- ✓ 3200.1.10 Relate inertia, force, or action-reaction forces to Newton’s three laws of motion and distinguish among the three laws in various scenarios.
- ✓ 3200.1.11 Compare, contrast, and apply the characteristic properties of scalar and vector quantities.

- ✓ 3200.1.12 Investigate the definitions of force, work, power, kinetic energy and potential energy.
- ✓ 3200.1.13 Analyze the characteristics of energy, and conservation of energy including friction, and gravitational potential energy.
- ✓ 3200.1.14 Investigate the buoyant force exerted on floating and submerged objects.
- ✓ 3200.1.15 Investigate the apparent weight of an object submerged in a fluid.
- ✓ 3200.1.16 Explain why objects float or sink in terms of force or density.
- ✓ 3200.1.17 Examine the motion of fluids.
- ✓ 3200.1.18 Recognize the effects of Bernoulli's principle on fluid motion (e.g., lift, ball trajectories, and wind around/over object).

Standard 2 – Thermodynamics

Conceptual Strand 2

The principles and laws of thermodynamics are essential for understanding the concept of energy.

Guiding Question 2

How do the laws of thermodynamics relate to understanding the conservation of energy?

Course Level Expectations

- CLE 3200.2.1 Explore the relationships among temperature, heat, and internal energy.
- CLE 3200.2.2 Compare Fahrenheit, Celsius, and Kelvin temperature scales.
- CLE 3200.2.3 Investigate exchanges in internal energy.

Checks for Understanding (Formative/Summative Assessment)

- ✓3200.2.1 Investigate the relationship between temperature and kinetic energy.
- ✓3200.2.2 Distinguish among internal energy, temperature, and heat.
- ✓3200.2.3 Investigate heat changes using calorimetry.
- ✓3200.2.4 Investigate energy changes associated with heats of fusion and vaporization.
- ✓3200.2.5 Explore thermal expansion and contraction.
- ✓3200.2.6 Apply the Second Law of Thermodynamics to the Carnot engine.
- ✓3200.2.7 Apply the Laws of Thermodynamics to atmospheric and climatic changes.
- ✓3200.2.8 Recognize that absolute zero is the absence of molecular kinetic energy.
- ✓3200.2.9 Relate the First Law of Thermodynamics as an application of the Law of Conservation of Energy to heat transfer through conduction, convection, and radiation.

Standard 3 – Waves and Optics

Conceptual Strand 3

Investigating wave behavior reveals information about sound and light.

Guiding Question 3

How does the wave model explain the phenomena of sound and light?

Course Level Expectations

- CLE 3200.3.1 Explore conditions associated with simple harmonic motion.
- CLE 3200.3.2 Investigate Hooke's law.
- CLE 3200.3.3 Understand wave mechanics.
- CLE 3200.3.4 Examine the Doppler Effect.
- CLE 3200.3.5 Explore the characteristics and properties of sound.
- CLE 3200.3.6 Describe the characteristics of the electromagnetic spectrum.
- CLE 3200.3.7 Investigate the interaction of light waves.
- CLE 3200.3.8 Explore the optical principles of mirrors and lenses.
- CLE 3200.3.9 Investigate the phenomenon of color.

Checks for Understanding (Formative/Summative Assessment)

- ✓ 3200.3.1 Investigate simple harmonic motion.
- ✓ 3200.3.2 Explore Hooke's Law.
- ✓ 3200.3.3 Investigate and analyze wavelength, frequency and amplitude of longitudinal and transverse waves.
- ✓ 3200.3.4 Compare mechanical and electromagnetic waves.
- ✓ 3200.3.5 Investigate reflection, refraction, diffraction, and interference of sound waves.
- ✓ 3200.3.6 Demonstrate the Doppler Effect.
- ✓ 3200.3.7 Determine the speed of sound experimentally and describe how various materials and temperatures affect wave transmission.
- ✓ 3200.3.8 Measure spring constants.
- ✓ 3200.3.9 Compare wave characteristics to natural auditory phenomena.
- ✓ 3200.3.10 Explore properties of the electromagnetic spectrum.
- ✓ 3200.3.11 Examine properties of light waves.
- ✓ 3200.3.12 Investigate reflection, refraction, diffraction, and interference of light waves.
- ✓ 3200.3.13 Investigate the polarization of plane and curved mirrors.
- ✓ 3200.3.14 Use ray tracings to solve optics of mirrors and lenses problems.
- ✓ 3200.3.15 Solve problems related to Snell's laws.
- ✓ 3200.3.16 Investigate optical phenomena (e.g., mirage, optical illusions, and dichromatic lens effect).
- ✓ 3200.3.17 Distinguish between coherent and incoherent light.
- ✓ 3200.3.18 Examine the properties of lasers.
- ✓ 3200.3.19 Explore the additive and subtractive properties associated with color formation.

Standard 4 – Electricity and Magnetism

Conceptual Strand 4

Various tools and equipment can be used to investigate the interplay between magnetic fields and the generation of electricity.

Guiding Question 4

What force and energy concepts are needed to explain magnetism and electricity?

Course Level Expectations

- CLE 3200.4.1 Distinguish among electric forces, electric charges, and electric fields.
- CLE 3200.4.2 Explore static and current electricity.
- CLE 3200.4.3 Investigate Ohm's law.
- CLE 3200.4.4 Compare and contrast series and parallel circuits.
- CLE 3200.4.5 Analyze components of electrical schematic diagrams.
- CLE 3200.4.6 Investigate magnetic poles, magnetic fields, and electromagnetic induction.

Checks for Understanding (Formative/Summative Assessment)

- ✓ 3200.4.1 Measure voltage, current, and resistance.
- ✓ 3200.4.2 Draw electric field lines, given a scenario of charged particles.
- ✓ 3200.4.3 Draw and explain series and parallel circuits.
- ✓ 3200.4.4 Identify components of series and parallel circuits and solve problems related to voltage, current, and resistance.
- ✓ 3200.4.5 Build series and parallel circuits and describe how they function.
- ✓ 3200.4.6 Demonstrate and explain electromagnetic induction.
- ✓ 3200.4.7 Sketch the magnetic field lines around a bar magnet.
- ✓ 3200.4.8 Create a simple electromagnet.

Standard 5 – Nuclear Science

Conceptual Strand 5

A deep understanding of particle physics is accomplished by investigating the principles of nuclear science.

Guiding Question 5

What particle physics concepts explain nuclear science?

Course Level Expectations

- CLE 3200.5.1 Investigate the properties and structure of the atom.
- CLE 3200.5.2 Explore the dynamics of the nucleus: radioactivity, nuclear decay, radiocarbon/uranium dating, and half-life.
- CLE 3200.5.3 Compare and contrast nuclear fission and nuclear fusion.
- CLE 3200.5.4 Investigate quantum theory.

Checks for Understanding (Formative/Summative Assessment)

- ✓ 3200.5.1 Identify the parts of an atom.
- ✓ 3200.5.2 Describe the properties and location of subatomic particles.
- ✓ 3200.5.3 Explain how particles behave like waves.
- ✓ 3200.5.4 Describe three forms of radioactivity in terms of changes in atomic number or mass number.
- ✓ 3200.5.5 Investigate the concept of half-life.
- ✓ 3200.5.6 Write balanced equations for the three forms of radioactive decay.
- ✓ 3200.5.7 Explain carbon-14 or uranium dating methods.

- ✓ 3200.5.8 Distinguish between nuclear fission and nuclear fusion in terms of transmutation.
- ✓ 3200.5.9 Investigate the history of nuclear science.

Tennessee Science Curriculum Framework

Biology II

Course Description

Biology II is a laboratory course that engages students in an in-depth study of biological principles. This course emphasizes internal and external structures and their functions, the environmental interactions of organisms, processes of living things, mechanisms that maintain homeostasis, biodiversity, and changes in life forms over time. Students explore all of the major biological concepts through an inquiry approach.

Biology II students investigate:

- Inquiry
- Technology and Engineering
- Cells
- Interdependence
- Flow of Matter and Energy
- Heredity
- Biodiversity and Change
- Comparative Anatomy and Physiology
- Botany

Embedded Inquiry

Conceptual Strand

Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21st century.

Guiding Question

What tools, skills, knowledge, and dispositions are needed to conduct scientific inquiry?

Course Level Expectations

CLE 3216.Inq.1 Recognize that science is a progressive endeavor that reevaluates and extends what is already accepted.

CLE 3216.Inq.2 Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.

CLE 3216.Inq.3 Use appropriate tools and technology to collect precise and accurate data.

CLE 3216.Inq.4 Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.

CLE 3216.Inq.5 Compare experimental evidence and conclusions with those drawn by others about the same testable question.

CLE 3216.Inq.6 Communicate and defend scientific findings.

Checks for Understanding (Formative/Summative Assessment)

- ✓3216.Inq.1 Trace the historical development of a scientific principle or theory, such as cell theory, evolution, or DNA structure.
- ✓3216.Inq.2 Conduct scientific investigations that include testable questions, verifiable hypotheses, and appropriate variables to explore new phenomena or verify the experimental results of others.
- ✓3216.Inq.3 Analyze the components of a properly designed scientific investigation.
- ✓3216.Inq.4 Select appropriate tools and technology to collect precise and accurate quantitative and qualitative data.
- ✓3216.Inq.5 Determine if data supports or contradicts a hypothesis or conclusion.
- ✓3216.Inq.6 Recognize, analyze, and evaluate alternative explanations for the same set of observations.
- ✓3216.Inq.7 Evaluate the accuracy and precision of data.
- ✓3216.Inq.8 Defend a conclusion based on scientific evidence.
- ✓3216.Inq.9 Determine why a conclusion is free of bias.
- ✓3216.Inq.10 Analyze experimental results and identify possible sources of experimental error.
- ✓3216.Inq.11 Formulate and revise scientific explanations and models using logic and evidence.
- ✓3216.Inq.12 Compare conclusions that offer different, but acceptable explanations for the same set of experimental data.

Embedded Technology and Engineering

Conceptual Strand

Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.

Guiding Question

How do science concepts, engineering skills, and applications of technology improve the quality of life?

Course Level Expectations

CLE 3216.T/E.1 Explore the impact of technology on social, political, and economic systems.

CLE 3216.T/E.2 Differentiate among elements of the engineering design cycle: design constraints, model building, testing, evaluating, modifying, and retesting.

CLE 3216.T/E.3 Explain the relationship between the properties of a material and the use of the material in the application of a technology.

CLE 3216.T/E.4 Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems.

Checks for Understanding (Formative/Summative Assessment)

- ✓3216.T/E.1 Distinguish among tools and procedures best suited to conduct a specified scientific inquiry.
- ✓3216.T/E.2 Apply the engineering design process to construct a prototype that meets developmentally appropriate specifications.
- ✓3216.T/E.3 Evaluate a protocol to determine the degree to which an engineering design process was successfully applied.
- ✓3216.T/E.4 Explore how the unintended consequences of new technologies can impact human and non-human communities.
- ✓3216.T/E.5 Evaluate the overall benefit to cost ratio of a new technology.
- ✓3216.T/E.6 Present research on current bioengineering technologies that advance health and contribute to improvements in our daily lives.
- ✓3216.T/E.7 Design a series of multi-view drawings that can be used by other students to construct an adaptive design and test its effectiveness.

Embedded Mathematics

Conceptual Strand

Science applies mathematics to investigate questions, solve problems, and communicate findings.

Guiding Question

What mathematical skills and understandings are needed to successfully investigate biological topics?

Course Level Expectations

- CLE 3216.Math.1 Understand the mathematical principles associated with the science of biology.
- CLE 3216.Math.2 Utilize appropriate mathematical equations and processes to understand biological concepts.

Checks for Understanding (Formative/Summative Assessment)

- ✓3216.Math.1 Choose, construct, and analyze appropriate graphical representations for a data set.
- ✓3216.Math.2 Analyze graphs to interpret biological events.
- ✓3216.Math.3 Make decisions about units, scales, and measurement tools that are appropriate for problem situations involving measurement.
- ✓3216.Math.4 Select and apply an appropriate method to evaluate the reasonableness of results.
- ✓3216.Math.5 Apply and interpret rates of change from graphical and numerical data.
- ✓3216.Math.6 Apply geometric properties, formulas, and relationships to interpret biological phenomena.
- ✓3216.Math.7 Use length, area, and volume to estimate and explain real-world problems.
- ✓3216.Math.8 Make predictions from a linear data set using a line of best fit.
- ✓3216.Math.9 Interpret a set of data using the appropriate measure of central tendency.

Standard 1 – Cells

Conceptual Strand 1

All living things are made of cells that perform functions necessary for life.

Guiding Question 1

How are cells organized to carry on the processes of life?

Course Level Expectations

- CLE 3216.1.1 Compare the characteristics of prokaryotic and eukaryotic cells.
- CLE 3216.1.2 Describe how fundamental life processes depend on chemical reactions that occur in specialized parts of the cell.
- CLE 3216.1.3 Explain how materials move into and out of cells.
- CLE 3216.1.4 Describe the enzyme-substrate relationship.
- CLE 3216.1.5 Investigate how proteins regulate the internal environment of a cell through communication and transport.
- CLE 3216.1.6 Describe the relationship between viruses and their host cells.

Checks for Understanding (Formative/Summative Assessment)

- ✓3216.1.1 Compare the organization and function of prokaryotic and eukaryotic cells.
- ✓3216.1.2 Conduct an experiment or simulation to demonstrate the movement of molecules through diffusion, facilitated diffusion, and active transport.
- ✓3216.1.3 Describe the composition and function of enzymes.
- ✓3216.1.4 Analyze the rate of reactions in which variables such as temperature, pH, and substrate and enzyme concentration are manipulated.
- ✓3216.1.5 Develop a flow chart that tracks a protein molecule from transcription through export from the cell.
- ✓3216.1.6 Describe the role of the ribosomes, endoplasmic reticulum, and Golgi apparatus in the production and packaging of proteins.
- ✓3216.1.7 Describe how carbohydrates, proteins, lipids, and nucleic acids function in the cell.
- ✓3216.1.8 Illustrate the interactions between a virus and a host cell.

Standard 2 – Interdependence

Conceptual Strand 2

All life is interdependent and interacts with the environment.

Guiding Question 2

How do living things interact with one another and with the non-living elements of their environment?

Course Level Expectations

- CLE 3216.2.1 Describe how the stability of an ecosystem is maintained.
- CLE 3216.2.2 Investigate the major factors that influence population size and age distribution.

CLE 3216.2.3 Describe the varying degrees to which individual organisms are able to accommodate changes in the environment.

CLE 3216.2.4 Distinguish between the accommodation of individual organisms and the adaptation of a population to environmental change.

Checks for Understanding (Formative/Summative Assessment)

- ✓3216.2.1 Analyze the ecological impact of a change in climate, human activity, introduction of non-native species, and changes in population size over time.
- ✓3216.2.2 Investigate how fluctuations in population size in an ecosystem are determined by the relative rates of birth, death, immigration, and emigration.
- ✓3216.2.3 Investigate how human changes to the environment have led populations to adapt, migrate, or become extinct.
- ✓3216.2.4 Contrast accommodations of individual organisms with the adaptation of a species.

Standard 3 – Flow of Matter and Energy

Conceptual Strand 3

Matter cycles and energy flows through the biosphere.

Guiding Question 3

What are the scientific explanations for how matter cycles and energy flows through the biosphere?

Course Level Expectations

CLE 3216.3.1 Describe the role of biotic and abiotic factors in the cycling of matter in the ecosystem.

CLE 3216.3.2 Explain how sunlight is captured by plant cells and converted into usable energy.

CLE 3216.3.3 Describe how mitochondria make stored chemical energy available to cells.

CLE 3216.3.4 Examine how macromolecules are synthesized from simple precursor molecules.

CLE 3216.3.5 Analyze the role of ATP in the storage and release of cellular energy.

Checks for Understanding (Formative/Summative Assessment)

- ✓3216.3.1 Describe how water, carbon, oxygen, and nitrogen cycle between the biotic and abiotic elements of the environment.
- ✓3216.3.2 Calculate the amount of energy transfer through an ecosystem.
- ✓3216.3.3 Design an experiment to separate plant leaf pigments.
- ✓3216.3.4 Develop a concept map or flow chart to compare the sequence of molecular events during photosynthesis and cellular respiration.
- ✓3216.3.5 Sequence the steps involved in sugar production during photosynthesis.
- ✓3216.3.6 Trace the breakdown of sugar molecules during cellular respiration.
- ✓3216.3.7 Compare the amount of ATP produced during aerobic and anaerobic respiration.

- ✓3216.3.8 Build models of macromolecules from simple precursors.

Standard 4 – Heredity

Conceptual Strand 4

Organisms reproduce and transmit hereditary information.

Guiding Question 4

What are the principal mechanisms by which living things reproduce and transmit hereditary information from parents to offspring?

Course Level Expectations

- CLE 3216.4.1 Describe how mutation and sexual reproduction contribute to the amount of genetic variation in a population.
- CLE 3216.4.2 Describe the relationship between phenotype and genotype.
- CLE 3216.4.3 Predict the probable outcome of genetic crosses based on Mendel's laws of segregation and independent assortment.
- CLE 3216.4.4 Describe the relationship among genes, the DNA code, production of protein molecules, and the characteristics of an organism.
- CLE 3216.4.5 Explain how the different shapes and properties of proteins are determined by the type, number, and sequence of amino acids.
- CLE 3216.4.6 Explain how the genetic makeup of cells can be engineered.

Checks for Understanding (Formative/Summative Assessment)

- ✓3216.4.1 Illustrate the movement of chromosomes and other cellular organelles involved in meiosis.
- ✓3216.4.2 Provide a detailed explanation of how meiosis and fertilization result in new genetic combinations.
- ✓3216.4.3 Compare the expected outcome with the actual results of a cross in an organism such as a fruit fly or fast plant.
- ✓3216.4.4 Develop a model to illustrate the stages of protein synthesis.
- ✓3216.4.5 Apply the genetic coding rules to predict the sequence of amino acids from a sequence of codons in RNA.
- ✓3216.4.6 Recognize how various types of mutations affect gene expression and the sequence of amino acids in the encoded protein.
- ✓3216.4.7 Distinguish among the characteristics of various structural levels found in protein molecules.
- ✓3216.4.8 Describe the formation of recombinant DNA molecules.
- ✓3216.4.9 Recognize that genetic engineering can be applied to develop novel biomedical and agricultural products.

Standard 5 – Biodiversity and Change

Conceptual Strand 5

A rich variety and complexity of organisms have developed in response to changes in the environment.

Guiding Question 5

How does natural selection explain how organisms have changed over time?

Course Level Expectations

CLE 3216.5.1 Identify factors that determine the frequency of an allele in the gene pool of a population.

CLE 3216.5.2 Determine how mutation, gene flow, and migration influence population structure.

Checks for Understanding (Formative/Summative Assessment)

✓3216.5.1 Predict how variation within a population affects the survival of a species.

✓3216.5.2 Recognize that natural selection acts on an organism's phenotype rather than its genotype.

✓3216.5.3 Describe how reproductive and geographic isolation affect speciation.

✓3216.5.4 Analyze population changes in terms of the Hardy-Weinberg principle.

✓3216.5.5 Explain how amount of biodiversity is affected by habitat alteration.

✓3216.5.6 Use fossil evidence, DNA structure, amino acid sequences, and other data sources to construct a cladogram that illustrates evolutionary relationships.

Standard 6 – Comparative Anatomy and Physiology

Conceptual Strand 6

All living organisms are both alike and different.

Guiding Question 6

In what ways are all living organisms similar and what makes a species unique?

Course Level Expectations

CLE 3216.6.1 Investigate the unity and the diversity among living things.

CLE 3216.6.2 Describe the events associated with reproduction from gamete production through birth.

CLE 3216.6.3 Compare organ systems of representative animal phyla that: regulate gas exchange, process and distribute nutrients, remove wastes, transmit chemical and electrical information, and respond to environmental stimuli.

Checks for Understanding (Formative/Summative Assessment)

✓3216.6.1 Describe how the activities of major body systems help to maintain homeostasis.

✓3216.6.2 Distinguish between various methods of sexual and asexual reproduction.

✓3216.6.3 Create a model that illustrates stages of embryological development.

- ✓3216.6.4 Develop a representation of the different germ layers and the tissue type into which they develop.
- ✓3216.6.5 Describe how the nervous and endocrine systems coordinate various body functions.
- ✓3216.6.6 Develop a multimedia product for an immune disorder or infectious disease to demonstrate the impact on the individual organism.
- ✓3216.6.7 Observe, model, manipulate, and/or dissect representative specimens of major animal groups.
- ✓3216.6.8 Compare and contrast the function of the major organ systems found in representative animal species.

Standard 7 – Botany

Conceptual Strand 7

Plants are essential for life to exist.

Guiding Question 7

What conditions are needed for plants to grow and reproduce?

Course Level Expectations

- CLE 3216.7.1 Describe different plant types plants based on their anatomy and physiology.
- CLE 3216.7.2 Investigate the relationship between form and function for the major plant structures.
- CLE 3216.7.3 Examine the anatomical and physiological differences between plants and their growth, reproduction, survival, and co-evolution.
- CLE 3216.7.4 Describe the difference between plants and fungi.
- CLE 3216.7.5 Investigate the impact of plants on humans.

Checks for Understanding (Formative/Summative Assessment)

- ✓3216.7.1 Describe the function of plant cellular organelles.
- ✓3216.7.2 Employ a dichotomous key to identify plants based on their structural characteristics.
- ✓3216.7.3 Distinguish between the following: vascular and nonvascular plants, spore and seed, gymnosperms and angiosperms, and monocots and dicots.
- ✓3216.7.4 Investigate the significance of structural and physiological adaptations of plants.
- ✓3216.7.5 Compare and contrast spore and seed production.
- ✓3216.7.6 Design an experiment to investigate the function of plant hormones.
- ✓3216.7.7 Prepare a presentation about plants that are harmful or beneficial to humans.
- ✓3216.7.8 Describe co-evolution among various plant and animal species.

Tennessee Science Curriculum Framework

Human Anatomy and Physiology

Course Description

Human Anatomy and Physiology is a laboratory science course that consists of an in-depth study of the body systems that maintain homeostasis from anatomical, physiological, and histological perspectives. Students explore the body's structures and functions through an inquiry approach.

Human Anatomy and Physiology students investigate:

- Inquiry
- Technology and Engineering
- Anatomical Orientation
- Protection, Support, and Movement
- Integration and Regulation
- Transportation
- Absorption and Excretion
- Reproduction, Growth, and Development

Embedded Inquiry

Conceptual Strand

Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21st century.

Guiding Question

What tools, skills, knowledge, and dispositions are needed to conduct scientific inquiry?

Course Level Expectations

CLE 3251.Inq.1 Recognize that science is a progressive endeavor that reevaluates and extends what is already accepted.

CLE 3251.Inq.2 Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.

CLE 3251.Inq.3 Use appropriate tools and technology to collect precise and accurate data.

CLE 3251.Inq.4 Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.

CLE 3251.Inq.5 Compare experimental evidence and conclusions with those drawn by others about the same testable question.

CLE 3251.Inq.6 Communicate and defend scientific findings.

Checks for Understanding (Formative/Summative Assessment)

- ✓3251.Inq.1 Trace the historical development of a scientific principle or theory, such as the cell theory, evolution, or DNA structure.
- ✓3251.Inq.2 Select a description or scenario that reevaluates and/or extends a scientific finding.
- ✓3251.Inq.3 Conduct scientific investigations that include testable questions, verifiable hypotheses, and appropriate variables to explore new phenomena or verify the experimental results of others.
- ✓3251.Inq.4 Select appropriate tools and technology to collect precise and accurate quantitative and qualitative data.
- ✓3251.Inq.5 Evaluate the accuracy and precision of data.
- ✓3251.Inq.6 Determine if data supports or contradicts a hypothesis or conclusion.
- ✓3251.Inq.7 Compare or combine experimental evidence from two or more investigations.
- ✓3251.Inq.8 Recognize, analyze, and evaluate alternative explanations for the same set of observations.
- ✓3251.Inq.9 Analyze experimental results and identify possible sources.
- ✓3251.Inq.10 Compare conclusions that offer different, but acceptable explanations for the same set of experimental data.
- ✓3251.Inq.11 Formulate and revise scientific explanations and models using logic and evidence.

Embedded Technology and Engineering

Conceptual Strand

Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.

Guiding Question

How do science concepts, engineering skills, and applications of technology improve the quality of life?

Course Level Expectations

- CLE 3251.T/E.1 Explore the impact of technology on social, political, and economic systems.
- CLE 3251.T/E.2 Differentiate among elements of the engineering design cycle: design constraints, model building, testing, evaluating, modifying, and retesting.
- CLE 3251.T/E.3 Explain the relationship between the properties of a material and the use of the material in the application of a technology.
- CLE 3251.T/E.4 Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems.

Checks for Understanding (Formative/Summative Assessment)

- ✓3251.T/E.1 Distinguish among tools and procedures best suited to conduct a specified scientific inquiry.

- ✓3251.T/E.2 Apply the engineering design process to construct a prototype that meets developmentally appropriate specifications.
- ✓3251.T/E.3 Evaluate a protocol to determine the degree to which an engineering design process was successfully applied.
- ✓3251.T/E.4 Explore how the unintended consequences of new technologies can impact human and non-human communities.
- ✓3251.T/E.5 Evaluate the overall benefit to cost ratio of a new technology.
- ✓3251.T/E.6 Present research on current bioengineering technologies that advance health and contribute to improvements in our daily lives.
- ✓3251.T/E.7 Design a series of multi-view drawings that can be used by other students to construct an adaptive design and test its effectiveness.

Standard 1 – Anatomical Orientation

Conceptual Strand 1

Anatomy and physiology investigates the interdependence of structure and function to form a living, integrated whole.

Guiding Question 1

How is the body organized to function effectively and maintain homeostasis?

Course Level Expectations

- CLE 3251.1.1 Distinguish between anatomy and physiology.
- CLE 3251.1.2 Investigate the interrelationship between the structures and functions of the body systems.
- CLE 3251.1.3 Investigate the body cavities, the subdivisions of each cavity, and the organs within each area.
- CLE 3251.1.4 Use correct anatomical terminology when discussing body structures, sections, and regions.
- CLE 3251.1.5 Describe the body mechanisms that maintain homeostasis.

Checks for Understanding (Formative/Summative Assessment)

- ✓3251.1.1 Illustrate the interconnections between anatomy and physiology using a concept map.
- ✓3251.1.2 Sequence the levels of structural organization from the molecular level through the organismic level.
- ✓3251.1.3 Use prepared slides to distinguish among different types of tissues.
- ✓3251.1.4 Classify organ systems of the body as either (1) protection, support, and movement, (2) regulation and integration (3) transport, and (4) absorption and excretion.
- ✓3251.1.5 Identify the major organs and describe the functions of each body system.
- ✓3251.1.6 Identify and label the body cavities including the subdivisions and organs of each.
- ✓3251.1.7 Apply correct terminology to reference anatomical orientation.
- ✓3251.1.8 Provide examples of bodily mechanisms that serve to maintain homeostasis.

- ✓3251.1.9 Explain how the body regulates temperature, blood carbon dioxide levels, and blood glucose levels.

Standard 2 – Protection, Support, Movement

Conceptual Strand 2

The integumentary, skeletal, and muscular systems work together to support, protect, and move body structures as well as maintain homeostasis.

Guiding Question 2

How do body systems aid in support, protection, and movement as well as in maintaining homeostasis?

Course Level Expectations

- CLE 3251.2.1 Identify structures of the integumentary, skeletal, and muscular systems and show the relationship between these structures and their functions.
- CLE 3251.2.2 Investigate physiological mechanisms that allow the integumentary, skeletal, and muscular systems to function.

Checks for Understanding (Formative/Summative Assessment)

- ✓3251.2.1 Identify the structures of the skin and explain their role in protecting the body and maintaining homeostasis.
- ✓3251.2.2 Explain the physiological processes involved in healing the skin and disorders of the skin.
- ✓3251.2.3 Construct a labeled model of the skin with descriptions of its functions.
- ✓3251.2.4 Distinguish between the different types of bones.
- ✓3251.2.5 Describe the physiological mechanisms involved in bone development, growth, and repair.
- ✓3251.2.6 Identify the major muscles of the body.
- ✓3251.2.7 Compare and contrast the axial and appendicular skeletons using a graphic organizer.
- ✓3251.2.8 Observe, draw, and label the different types of muscle tissue noting their functions and structure.
- ✓3251.2.9 Illustrate the major steps of the sliding filament theory of muscle contraction.

Standard 3 – Integration and Regulation

Conceptual Strand 3

The nervous and endocrine systems work in an integrative manner to maintain homeostasis and communicate with all other body systems.

Guiding Question 3

What external and internal bodily mechanisms are involved in communication, control, growth, and development?

Course Level Expectations

- CLE 3251.3.1 Compare and contrast the anatomy and physiology of the central and peripheral nervous systems.
- CLE 3251.3.2 Describe the structure, function, and developmental aspects of neurons and their supporting glial cells.
- CLE 3251.3.3 Investigate the physiology of electrochemical impulses and neural integration.
- CLE 3251.3.4 Investigate organs for perception of external stimuli and to the maintenance of homeostasis.
- CLE 3251.3.5 Identify the major organs of the endocrine system and the associated hormonal production and regulation.

Checks for Understanding (Formative/Summative Assessment)

- ✓3251.3.1 Identify the major areas of the brain and the major structures of the spinal cord.
- ✓3251.3.2 Identify the structure and function of cranial nerves, neurons, neuroglia, and neuromuscular junctions.
- ✓3251.3.3 Use a graphic organizer to trace the pathways and biochemical changes associated with conduction of an electrochemical impulse.
- ✓3251.3.4 Construct a model to describe the molecular neurophysiology of membrane potentials in terms of electrolyte function and active transport.
- ✓3251.3.5 Identify the structures and functions of the body's sensory organs.
- ✓3251.3.6 Differentiate among the major organs and tissues that comprise the endocrine system.
- ✓3251.3.7 Explain how the hormones secreted by endocrine glands regulate the body.
- ✓3251.3.8 Interpret graphs of blood sugar levels in terms of pancreatic function.
- ✓3251.3.9 Analyze a case study of a neurological disorder to make a speculative diagnosis or prognosis.

Standard 4 – Transport

Conceptual Strand 4

The cardiovascular system transports materials pumped by the heart through blood vessels to all parts of the body. The lymphatic system bathes the body in extracellular fluid and works with the cardiovascular system to provide immunity and regulate fat metabolism.

Guiding Question 4

*How does the cardiovascular system transport substances that maintain homeostasis?
What mechanisms are involved in staying healthy through the immune responses?*

Course Level Expectations

- CLE 3251.4.1 Identify the molecular and cellular components of the blood and the functions of the blood.
- CLE 3251.4.2 Explore the anatomy of the heart and describe the pathway of blood through this organ.

- CLE 3251.4.3 Describe the biochemical and physiological nature of heart function.
- CLE 3251.4.4 Describe the relationship between the structure and function of different types of blood vessels.
- CLE 3251.4.5 Describe the physiological basis of circulation and blood pressure.
- CLE 3251.4.6 Identify the structures of the lymphatic system.
- CLE 3251.4.7 Describe the details of the immune response.

Checks for Understanding (Formative/Summative Assessment)

- ✓3251.4.1 Describe the different types of blood vessels.
- ✓3251.4.2 Identify the major arteries and veins.
- ✓3251.4.3 Describe the cellular components and physical characteristics of blood.
- ✓3251.4.4 Determine blood types in the ABO system.
- ✓3251.4.5 Prepare a model that illustrates the layers, chambers, and valves of the heart.
- ✓3251.4.6 Describe the biochemical and physiological events associated with heart contraction, blood pressure, and blood clotting.
- ✓3251.4.7 Measure blood pressure and the pulse rates.
- ✓3251.4.8 Draw a diagram that traces the pathway of blood through the heart and lungs.
- ✓3251.4.9 Compare the molecular affinity of hemoglobin to oxygen and carbon monoxide in terms of maintaining homeostasis.
- ✓3251.4.10 Describe the immune response mechanisms at the cellular level.
- ✓3251.4.11 Relate nonspecific cellular and chemical defenses of the body to environmental factors.
- ✓3251.4.12 Identify the causes of imbalances in the immune system.

Standard 5 – Absorption and Excretion

Conceptual Strand 5

The digestive system takes in food and changes it to a usable form. The urinary system removes wastes and maintains osmotic balance.

Guiding Question 5

How does the digestive system convert food into the raw materials that build and fuel the body's cells? How does the urinary system maintain the homeostatic balance of internal fluids?

Course Level Expectations

- CLE 3251.5.1 Identify organs of the digestive and urinary systems and describe their functions.
- CLE 3251.5.2 Investigate mechanisms of digestion and food absorption.
- CLE 3251.5.3 Describe how nutrition, metabolism, and body temperature are related.
- CLE 3251.5.4 Explain how the kidneys function to remove wastes from the blood.

Check for Understanding (Formative/Summative Assessment)

- ✓3251.5.1 Compare the structure and function of organs in the digestive system.
- ✓3251.5.2 Contrast mechanical and chemical digestion
- ✓3251.5.3 Trace a selected food through the alimentary canal.

- ✓3251.5.4 Identify the enzymes and biochemical reactions that facilitate digestion.
- ✓3251.5.5 Explain how the products of digestion are absorbed.
- ✓3251.5.6 Compare and contrast the male and female urinary systems.
- ✓3251.5.7 Explain how the kidneys act to maintain homeostasis.
- ✓3251.5.8 Identify the parts of a nephron and describe how they assist in urine formation.
- ✓3251.5.9 Describe the composition of urine.
- ✓3251.5.10 Describe a countercurrent mechanism and explain how it concentrates urine.
- ✓3251.5.11 Discuss the importance of water and electrolyte balance.
- ✓3251.5.12 Describe how body temperature is regulated.

Standard 6 – Reproduction, Growth, and Development

Conceptual Strand 6

The reproductive system ensures the continuity of a species.

Guiding Question 6

How do the organs and structures of the reproductive system function to produce successive generations of offspring?

Course Level Expectations

CLE 3251.6.1 Identify the essential and accessory organs of the male and female reproductive systems and describe their functions.

CLE 3251.6.2 Explain hormonal regulation during a typical 28 day menstrual cycle.

CLE 3251.6.3 Summarize the principal events that occur during prenatal development.

Check for Understanding (Formative/Summative Assessment)

- ✓3251.6.1 Relate the structures of the male and female reproductive systems to their functions.
- ✓3251.6.2 Describe the role of hormones in controlling the secondary sex characteristics.
- ✓3251.6.3 Compare and contrast the processes and products of oogenesis and spermatogenesis.
- ✓3251.6.4 Trace the pathway that sperm travel from the testes to the exterior of the body.
- ✓3251.6.5 Summarize the events of the menstrual cycle.
- ✓3251.6.6 Describe the hormonal control mechanisms that regulate the menstrual cycle.
- ✓3251.6.7 Sequence the stages of human development from fertilization to birth.
- ✓3251.6.8 Describe the functions of the placenta.
- ✓3251.6.9 Research and describe methods of controlling human fertility, and describe their relative effectiveness.

Tennessee Science Curriculum Framework

Ecology

Course Description

Ecology is a laboratory course that enables students to develop an understanding of the natural and man-made environment and the environmental problems the world faces. Students explore ecological concepts through an inquiry approach.

Ecology students investigate:

- Inquiry
- Technology and Engineering
- Individuals
- Populations
- Communities
- Ecosystems
- Biomes
- Humans and Sustainability

Embedded Inquiry

Conceptual Strand

Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21st century.

Guiding Question

What tools, skills, knowledge, and dispositions are needed to conduct scientific inquiry?

Course Level Expectations

CLE 3255.Inq.1 Recognize that science is a progressive endeavor that reevaluates and extends what is already accepted.

CLE 3255.Inq.2 Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.

CLE 3255.Inq.3 Use appropriate tools and technology to collect precise and accurate data.

CLE 3255.Inq.4 Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.

CLE 3255.Inq.5 Compare experimental evidence and conclusions with those drawn by others about the same testable question.

CLE 3255.Inq.6 Communicate and defend scientific findings.

Checks for Understanding (Formative/Summative Assessment)

- ✓3255.Inq.1 Develop a testable question for a scientific investigation.
- ✓3255.Inq.2 Develop an experimental design for testing a hypothesis.
- ✓3255.Inq.3 Select appropriate independent, dependent, or controlled variables for an experiment.
- ✓3255.Inq.4 Perform an experiment to test a prediction.
- ✓3255.Inq.5 Gather, organize, and transform data from an experiment.
- ✓3255.Inq.6 Analyze and interpret the results of an experiment.
- ✓3255.Inq.7 Use knowledge and data-interpretation skills to support a conclusion.
- ✓3255.Inq.8 State a conclusion in terms of the relationship between two or more variables.
- ✓3255.Inq.9 Compare the results of an experiment with what is already known about the topic under investigation.
- ✓3255.Inq.10 Suggest alternative explanations for the same observations.
- ✓3255.Inq.11 Analyze experimental results and identify the nature and sources of experimental error.
- ✓3255.Inq.12 Formulate and revise scientific explanations and models using logic and evidence.
- ✓3255.Inq.13 Develop a logical argument about cause-and-effect relationships in an experiment.

Embedded Technology and Engineering

Conceptual Strand

Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.

Guiding Question

How do science concepts, engineering skills, and applications of technology improve the quality of life?

Course Level Expectations

- CLE 3255.T/E.1 Explore the impact of technology on social, political, and economic systems.
- CLE 3255.T/E.2 Differentiate among elements of the engineering design cycle: design constraints, model building, testing, evaluating, modifying, and retesting.
- CLE 3255.T/E.3 Explain the relationship between the properties of a material and the use of the material in the application of a technology.
- CLE 3255.T/E.4 Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems.

Checks for Understanding (Formative/Summative Assessment)

- ✓3255. T/E.1 Select appropriate tools to conduct a scientific inquiry.
- ✓3255. T/E.2 Apply the engineering design process to construct a prototype that meets developmentally appropriate specifications.

- ✓3255. T/E.3 Explore how the unintended consequences of new technologies can impact human and non-human communities.
- ✓3255. T/E.4 Present research on current bioengineering technologies that advance health and contribute to improvements in our daily lives.
- ✓3255. T/E.5 Design a series of multi-view drawings that can be used by other students to construct an adaptive design and test its effectiveness.

Standard 1 – Individuals

Conceptual Strand 1

The individual organism is the basic unit of ecology.

Guiding Question 1

What determines the survival of individuals in a population?

Course Level Expectations

- CLE 3255.1.1 Analyze strategies for classifying organisms.
- CLE 3255.1.2 Identify organisms based on how they obtain energy.
- CLE 3255.1.3 Relate specific animal behaviors and plant tropisms to survival.
- CLE 3255.1.4 Investigate various approaches to maintain biodiversity.

Checks for Understanding (Formative/Summative Assessment)

- ✓3255.1.1 Develop a visual aid to illustrate the major characteristics of the six kingdoms.
- ✓3255.1.2 Use a dichotomous key to identify at least five species found in a local ecosystem.
- ✓3255.1.3 Distinguish among primary, secondary and tertiary consumers.
- ✓3255.1.4 Distinguish among herbivores, carnivores, and omnivores.
- ✓3255.1.5 Distinguish between photosynthesis and chemosynthesis and describe organisms that occupy these niches in both terrestrial and aquatic habitats.
- ✓3255.1.6 Investigate animal behavior by observing common invertebrates: termites, isopods, mealworms or bess beetles.
- ✓3255.1.7 Using simple materials create a living display of photo-, hydro- and geotropisms.
- ✓3255.1.8 Investigate techniques and findings of the All Taxa Biodiversity Inventories (ATBI) underway in the Great Smoky Mountains National Park and Tennessee State Parks.
- ✓3255.1.9 Explore careers in conservation biology and bioinformatics.

Standard 2 – Populations

Conceptual Strand 2

A population is composed of a single species within a specified area.

Guiding Question 2

What are some characteristics of populations?

Course Level Expectations

- CLE 3255.2.1 Cite examples of populations limited by natural factors, humans or both.
- CLE 3255.2.2 Explain population growth patterns and rates.
- CLE 3255.2.3 Summarize how natural selection influences a population over time.

Checks for Understanding (Formative/Summative Assessment)

- ✓3255.2.1 Define population and describe several examples of populations in different ecosystems.
- ✓3255.2.2 Identify distribution patterns (random, uniform, clumped with groups random) and populations that exhibit each of these patterns.
- ✓3255.2.3 Using a population of yeast, duckweed or other suitable species, design and conduct an experiment to evaluate population growth and carrying capacity.
- ✓3255.2.4 Categorize limiting factors as density dependent or density independent, human influenced or non-human influenced, and biotic or abiotic when given scenarios.
- ✓3255.2.5 Evaluate populations based on age structure, distribution, and density.
- ✓3255.2.6 Draw and/or label population growth curves representing exponential growth, logistic growth and carrying capacity.
- ✓3255.2.7 Illustrate the type of survivorship curves created by r-strategists and K-strategists.
- ✓3255.2.8 Research case studies (Tasmanian sheep, St. Matthew's Island reindeer, Isle Royale) to illustrate the consequences of logistic and exponential growth.
- ✓3255.2.9 Compare case studies of evolution such as Galapagos finches, peppered moths, and salamanders in the Smoky Mountains.

Standard 3 – Communities

Conceptual Strand 3

Communities are groups of interacting populations.

Guiding Question 3

How do populations interact to produce stable communities?

Course Level Expectations

- CLE 3255.3.1 Explain ecological niches within various habitats.
- CLE 3255.3.2 Relate species interactions such as competition, predation and symbiosis to coevolution.
- CLE 3255.3.3 Apply the first and second laws of thermodynamics to explain the flow of energy through a food chain or web.
- CLE 3255.3.4 Analyze how biomass is related to trophic levels.

Checks for Understanding (Formative/Summative Assessment)

- ✓3255.3.1 Describe the difference between a fundamental niche and a realized niche.
- ✓3255.3.2 Create a chart to compare and contrast specialist and generalist species and describe environmental conditions that favor these two approaches.

- ✓3255.3.3 Distinguish among the following roles and cite Tennessee examples of each: native species, non-native species, invasive species, indicator species, “keystone” species.
- ✓3255.3.4 Discuss how competition and predation regulate population size.
- ✓3255.3.5 Summarize the principles of competitive exclusion and resource partitioning.
- ✓3255.3.6 Distinguish among the three forms of symbiotic relationships.
- ✓3255.3.7 Describe structural and behavioral adaptations for survival used by predators and prey.
- ✓3255.3.8 Explain energy pyramids and the “Rule of 10” as they relate to the first and second laws of thermodynamics.
- ✓3255.3.9 Create a food web characteristic of a Tennessee ecoregion composed of at least four trophic levels.

Standard 4 – Ecosystems

Conceptual Strand 4

An ecosystem is a community that interacts with the physical environment.

Guiding Question 4

How do ecosystems change over time?

Course Level Expectations

- CLE 3255.4.1 Describe the flow of energy flow through an ecosystem.
- CLE 3255.4.2 Describe how matter cycles through various biogeochemical cycles.
- CLE 3255.4.3 Evaluate the process of succession.
- CLE 3255.4.4 Summarize the human impact on ecosystems.
- CLE 3255.4.5 Describe how biodiversity relates to stability of an ecosystem.

Checks for Understanding (Formative/Summative Assessment)

- ✓3255.4.1 Trace energy flow from the sun through living organisms.
- ✓3255.4.2 Illustrate each of the following biogeochemical cycles: water, carbon, nitrogen, and phosphorus.
- ✓3255.4.3 Distinguish between primary and secondary biological succession.
- ✓3255.4.4 Explore a local area and examine the abiotic and biotic factors relating to succession and ecosystem structure.
- ✓3255.4.5 Summarize how disturbance contributes to succession and ecosystem stability.
- ✓3255.4.6 Identify how nutrient availability affects terrestrial and aquatic ecosystems.
- ✓3255.4.7 Design an ecosystem in the classroom (terrarium, bottle biology, eco-column, etc.) for making observations, conducting experiments and long-term monitoring.
- ✓3255.4.8 Create a concept map relating the events that lead to the parachuting of cats on Borneo by the World Health Organization.

Standard 5 – Biomes

Conceptual Strand 5

A biome is a region of the earth with characteristic types of natural ecological communities.

Guiding Question 5

How are earth's biomes distributed?

Course Level Expectations

CLE 3255.5.1 Explain how climate influences terrestrial biomes.

CLE 3255.5.2 Compare and contrast the major terrestrial biomes: deserts, temperate grasslands, temperate forests, tropical grasslands, tropical forests, taiga and tundra.

CLE 3255.5.3 Examine the major marine and freshwater biomes.

CLE 3255.5.4 Infer how organisms in different biomes occupy similar niches.

CLE 3255.5.5 Identify how humans impact biomes.

Checks for Understanding (Formative/Summative Assessment)

✓3255.5.1 Illustrate how temperature, precipitation, latitude, and altitude influence terrestrial biomes.

✓3255.5.2 Research and create a visual to summarize the climate, soil, location, plant adaptations, animal adaptations, and human threats to each of the major terrestrial biomes.

✓3255.5.3 Research and create a visual to summarize abiotic factors, location, plant adaptations, animal adaptations, and human threats to marine and freshwater biomes.

✓3255.5.4 Research wetlands in your area and write a persuasive letter to a public official concerning the protection of wetlands.

✓3255.5.5 Compare two or more ecological equivalents and how they are specifically adapted to their particular biome (black/grizzly bears, Asian/African elephants, snowshoe/cottontail/jack rabbit).

Standard 6 – Humans and Sustainability

Conceptual Strand 6

Human activities have reduced the earth's biodiversity.

Guiding Question 6

What can individuals do to sustain biodiversity locally and globally?

Course Level Expectations

CLE 3255.6.1 Investigate the role of public lands in sustaining biodiversity.

CLE 3255.6.2 Examine state, national, and international efforts to sustain native species and ecosystems.

CLE 3255.6.3 Evaluate the impact of personal actions on the environment.

CLE 3255.6.4 Identify and explain choices you can make to lessen your impact on the environment.

Checks for Understanding (Formative/Summative Assessment)

- ✓3255.6.1 Differentiate the purposes of State and National Parks, Wildlife Refuges, and Forests.
- ✓3255.6.2 Design a vacation brochure, poster, slide show presentation or commercial advertisement that extols the virtues of a given area (e.g., state or national parks/forests) and ecotourism opportunities that may be found there.
- ✓3255.6.3 Research and paraphrase local, national, and international environmental legislation enacted to sustain biodiversity (e.g., The Lacey Act, Endangered Species Act, National Marine Fisheries Act, TWRA Hunting and Fishing Regulations, CITES).
- ✓3255.6.4 Develop a timeline that illustrates major local, national and international environmental legislation enacted to sustain biodiversity.
- ✓3255.6.5 Find out what watershed your school is located in and how wastewater, municipal solid, and hazardous wastes are handled.
- ✓3255.6.6 Research issues surrounding the adoption of environmentally and socially responsible behaviors (e.g., proper waste disposal, using fuel efficient transportation, planting native species, purchasing locally grown food, reducing/eliminating dependence on ‘one use’ products).
- ✓3255.6.7 Create a list of the “Five Biggest Threats to the Global Environment.”

Tennessee Science Curriculum Framework

Scientific Research

Course Description

Scientific Research is a laboratory course that enables the student to both apply and expand previous content knowledge toward the endeavor of engaging in an open-ended, student-centered investigation in the pursuit of an answer to a question or problem of interest.

Scientific Research students investigate:

- Technology and Engineering
- Practice Ethics
- Think Critically
- Investigate (*note: these CLEs substitute for the 9-12 Embedded Inquiry Strand*)
- Analyze and Evaluate Data
- Communicate Results

Embedded Technology and Engineering

Conceptual Strand

Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.

Guiding Question

How do science concepts, engineering skills, and applications of technology improve the quality of life?

Course Level Expectations

CLE 3295.T/E.1 Explore the impact of technology on social, political, and economic systems.

CLE 3295.T/E.2 Differentiate among elements of the engineering design cycle: design constraints, model building, testing, evaluating, modifying, and retesting.

CLE 3295.T/E.3 Explain the relationship between the properties of a material and the use of the material in the application of a technology.

CLE 3295.T/E.4 Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems.

Checks for Understanding (Formative/Summative Assessment)

- ✓3295.T/E.1 Distinguish among tools and procedures best suited to conduct a specified scientific inquiry.
- ✓3295.T/E.2 Apply the engineering design process to construct a prototype that meets developmentally appropriate specifications.

- ✓3295.T/E.3 Evaluate a protocol to determine the degree to which an engineering design process was successfully applied.
- ✓3295.T/E.4 Explore how the unintended consequences of new technologies can impact human and non-human communities.
- ✓3295.T/E.5 Evaluate the overall benefit to cost ratio of a new technology.
- ✓3295.T/E.6 Present research on current technologies that advance health and contribute to improvements in our daily lives.
- ✓3295.T/E.7 Design a series of multi-view drawings that can be used by other students to construct an adaptive design and test its effectiveness.

Standard 1 – Practice Ethics

Conceptual Strand 1

Ethical practices must be adhered to during scientific research.

Guiding Question 1

What are the ethical practices that must be addressed while conducting scientific research?

Course Level Expectations

- CLE 3295.1.1 Critically examine data to determine its significance.
- CLE 3295.1.2 Repeat trials to enhance the reliability of data.
- CLE 3295.1.3 Recognize that in science one solution often leads to new questions.
- CLE 3295.1.4 Employ ethical practices during research and investigations that involve human or animal subjects and hazardous materials.
- CLE 3295.1.5 Follow safety procedures in the classroom, laboratory, and home environments.
- CLE 3295.1.6 Respect and understand copyright and patent laws.

Checks for Understanding (Formative/Summative Assessment)

- ✓ 3295.1.1 Choose appropriate sources of information.
- ✓ 3295.1.2 Use printed references and correct citations to credit all sources of information.
- ✓ 3295.1.3 Conduct a laboratory experiment to demonstrate knowledge of proper safety procedures.
- ✓ 3295.1.4 Describe reasons for honoring copyright laws.
- ✓ 3295.1.5 Survey the web for information concerning a scientific problem and differentiate between reliable and unreliable sources.
- ✓ 3295.1.6 Compose a review of literature using a proper format (e.g., APA, MLA).
- ✓ 3295.1.7 Complete a research plan that adheres to appropriate regulatory guidelines.
- ✓ 3295.1.8 Create entries in a journal showing date, accurate observations, collection of data, and other pertinent information.

Standard 2 –Think Critically

Conceptual Strand 2

Critical thinking skills are essential for identifying and solving scientific problems.

Guiding Question 2

What critical thinking skills are needed to answer researchable questions?

Course Level Expectations

- CLE 3295.2.1 Analyze and study classic scientific problems.
- CLE 3295.2.2 Use scientific instruments to extend the human senses in observation.
- CLE 3295.2.3 Recognize the limitations of scientific investigations.
- CLE 3295.2.4 Use technological tools and mathematical models to analyze problems or questions.
- CLE 3295.2.5 Evaluate safety implications and risks associated with answering a question.

Checks for Understanding (Formative/Summative Assessment)

- ✓3295.2.1 Compare the results of an experiment with what is already known about the topic under investigation.
- ✓3295.2.2 Employ a search engine on the Internet.
- ✓3295.2.3 Develop and refine a problem statement.
- ✓3295.2.4 Formulate a research plan that addresses a problem to be solved.
- ✓3295.2.5 Develop an awareness of the limitations to scientific investigations.
- ✓3295.2.6 Compare risks and benefits involved with solving a problem.
- ✓3295.2.7 Demonstrate correct use of scientific instruments.
- ✓3295.2.8 Anticipate safety issues during experimental design.
- ✓3295.2.9 Recognize the value of collaboration and division of labor within a team.
- ✓3295.2.10 Analyze questions using technology and mathematical models.
- ✓3295.2.11 Use mathematical and computational models to analyze questions derived from the scientific research problem.
- ✓3295.2.12 Write narrative descriptions of observed scientific phenomena.

Standard 3 – Investigate

Conceptual Strand 3

Investigative strategies are essential to answer a scientific question or solve a scientific problem.

Guiding Question 3

What strategies should be employed to solve a scientific problem or answer a scientific question?

Course Level Expectations

- CLE 3295.3.1 Formulate a working hypothesis to guide research.
- CLE 3295.3.2 Develop experimental procedures to test a hypothesis.

- CLE 3295.3.3 Practice appropriate safety procedures.
- CLE 3295.3.4 Collect data using a variety of scientific tools and equipment.
- CLE 3295.3.5 Verify data for accuracy.

Checks for Understanding (Formative/Summative Assessment)

- ✓ 3295.3.1 Develop a testable question for a scientific investigation.
- ✓ 3295.3.2 Differentiate between variables and controls in an experiment and select appropriate variables for an experiment.
- ✓ 3295.3.3 Develop an experimental design with proper application of controls and variables for testing a hypothesis.
- ✓ 3295.3.4 Perform an experiment to test a prediction.
- ✓ 3295.3.5 Design and use appropriate procedures for laboratory and fieldwork.
- ✓ 3295.3.6 Apply appropriate safety guidelines.
- ✓ 3295.3.7 Make correct use of scientific materials.
- ✓ 3295.3.8 Demonstrate appropriate measurement techniques.
- ✓ 3295.3.9 Maintain a well-documented project journal.
- ✓ 3295.3.10 Modify or design an alternative experimental procedure to test a hypothesis.
- ✓ 3295.3.11 Apply established procedures to novel situations.

Standard 4 – Analyze and Evaluate Data

Conceptual Strand 4

To synthesize, analyze, and evaluate data is a vital part of solving scientific problem solving.

Guiding Question 4

What problem solving skills are necessary to synthesize, analyze, and evaluate data in order to draw accurate conclusions?

Course Level Expectations

- CLE 3295.4.1 Use statistical analysis to accurately analyze and interpret data.
- CLE 3295.4.2 Evaluate data based in terms of its accuracy and precision.
- CLE 3295.4.3 Draw conclusions based on data analysis and evaluations.

Checks for Understanding (Formative/Summative Assessment)

- ✓ 3295.4.1 Collect data with hand-held technology.
- ✓ 3295.4.2 Use graphing calculators or computers to process data.
- ✓ 3295.4.3 Use spreadsheets, graphing, and database programs to transform data into a table, graph, or diagram.
- ✓ 3295.4.4 Distinguish between accuracy and precision.
- ✓ 3295.4.5 Analyze alternate methods for representing data graphically and interpret the results of an experiment.
- ✓ 3295.4.6 State a conclusion in terms of the relationship between two or more variables.
- ✓ 3295.4.7 Examine trends in data in order to answer questions.
- ✓ 3295.4.8 Analyze experimental results and identify the nature and sources of experimental error.

- ✓ 3295.4.9 Apply knowledge and data-interpretation skills to support a conclusion.
- ✓ 3295.4.10 Suggest alternative explanations for the same observations.
- ✓ 3295.4.11 Explain whether the data supports or contradicts the original hypothesis.
- ✓ 3295.4.12 Develop alternative hypotheses.
- ✓ 3295.4.13 Formulate and revise scientific explanations and models using logic and evidence.
- ✓ 3295.4.14 Develop a logical argument about cause-and-effect relationships in an experiment.

Standard 5 – Communicate Results

Conceptual Strand 5

Results of scientific investigations should be shared in oral and written form to a variety of audiences.

Guiding Question 5

How and with whom should the methods and results of scientific investigations be shared?

Course Level Expectations

- CLE 3295.5.1 Present a scientific report in a clear, accurate, and appropriate manner to an audience.
- CLE 3295.5.2 Communicate findings in order to extend the research base.

Checks for Understanding (Formative/Summative Assessment)

- ✓3295.5.1 Demonstrate advanced keyboarding skills.
- ✓3295.5.2 Apply proper grammatical conventions to written communication.
- ✓3295.5.3 Present research findings in expository form.
- ✓3295.5.4 Organize written communication with clarity and cohesion.
- ✓3295.5.5 Design and implement an appropriate presentation format based upon the audience and nature of the research.
- ✓3295.5.6 Present an effective and well-articulated oral report using audiovisual aids.
- ✓3295.5.6 Prepare a technical paper for potential publication.

Tennessee Science Curriculum Framework

Physics

Course Description

Physics is a laboratory course that examines the relationship between matter and energy and how they interact. This course will have a strong emphasis in the mathematics of physics. Students explore physics concepts through an inquiry approach.

Physics students investigate:

- Inquiry
- Technology and Engineering
- Mathematics of Physics
- Mechanics
- Thermodynamics
- Waves and Sound
- Light and Optics
- Electricity and Magnetism
- Atomic and Nuclear Physics

Embedded Inquiry

Conceptual Strand

Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21st century.

Guiding Question

What tools, skills, and knowledge are needed to conduct scientific inquiry?

Course Level Expectations

CLE 3231.Inq.1 Recognize that science is a progressive endeavor that reevaluates and extends what is already accepted.

CLE 3231.Inq.2 Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.

CLE 3231.Inq.3 Use appropriate tools and technology to collect precise and accurate data.

CLE 3231.Inq.4 Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.

CLE 3231.Inq.5 Compare experimental evidence and conclusions with those drawn by others about the same testable question.

CLE 3231.Inq.6 Communicate and defend scientific findings.

Checks for Understanding (Formative/Summative Assessment)

- ✓3231.Inq.1 Trace the historical development of a scientific principle or theory.
- ✓3231.Inq.2 Conduct scientific investigations that include testable questions, verifiable hypotheses, and appropriate variables to explore new phenomena or verify the experimental results of others.
- ✓3231.Inq.3 Select appropriate independent, dependent, or controlled variables for an experiment.
- ✓3231.Inq.4 Analyze the components of a properly designed scientific investigation.
- ✓3231.Inq.5 Perform an experiment to test a prediction.
- ✓3231.Inq.6 Select appropriate tools and technology to collect precise and accurate quantitative and qualitative data.
- ✓3231.Inq.7 Determine if data supports or contradicts a hypothesis or conclusion.
- ✓3231.Inq.8 Recognize, analyze, and evaluate alternative explanations for the same set of observations.
- ✓3231.Inq.9 Evaluate the accuracy and precision of data.
- ✓3231.Inq.10 State a conclusion in terms of the relationship between two or more variables.
- ✓3231.Inq.11 Defend a conclusion based on scientific evidence.
- ✓3231.Inq.12 Analyze experimental results and identify possible sources of bias or experimental error.
- ✓3231.Inq.13 Compare the results of an experiment with what is already known about the topic under investigation.
- ✓3231.Inq.14 Suggest alternative explanations for the same set of observations.
- ✓3231.Inq.15 Formulate and revise scientific explanations and models using logic and evidence.
- ✓3231.Inq.16 Compare conclusions that offer different, but acceptable explanations for the same set of experimental data.

Embedded Technology and Engineering

Conceptual Strand

Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.

Guiding Question

How do science concepts, engineering skills, and applications of technology improve the quality of life?

Course Level Expectations

- CLE 3231.T/E.1 Explore the impact of technology on social, political, and economic systems.
- CLE 3231.T/E.2 Differentiate among elements of the engineering design cycle: design constraints, model building, testing, evaluating, modifying, and retesting.
- CLE 3231.T/E.3 Explain the relationship between the properties of a material and the use of the material in the application of a technology.

CLE 3231.T/E.4 Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems.

Checks for Understanding (Formative/Summative Assessment)

- ✓3231.T/E.1 Select appropriate tools and procedures best suited to conduct a specified scientific inquiry.
- ✓3231.T/E.2 Apply the engineering design process to construct a prototype that meets developmentally appropriate specifications.
- ✓3231.T/E.3 Evaluate a protocol to determine the degree to which an engineering design process was successfully applied.
- ✓3231.T/E.4 Explore how the unintended consequences of new technologies can impact human and non-human communities.
- ✓3231.T/E.5 Evaluate the overall benefit to cost ratio of a new technology.
- ✓3231.T/E.6 Present research on current engineering technologies that contribute to improvements in our daily lives.
- ✓3231.T/E.7 Design a series of multi-view drawings that can be used by others to construct an adaptive design and test its effectiveness.

Embedded Mathematics

Conceptual Strand

Physics applies mathematics to investigate questions, solve problems, and communicate findings.

Guiding Question

What mathematical skills and understandings are needed to successfully investigate physics?

Course Level Expectations

- CLE.3231.Math.1 Graph relationships and functions between manipulated (independent) variables and responding (dependent) variables.
- CLE.3231.Math.2 Solve for variables in an algebraic formula.
- CLE.3231.Math.3 Apply statistical techniques to manipulate data.
- CLE.3231.Math.4 Investigate trigonometric connections to physics.
- CLE.3231.Math.5 Utilize calculus to understand physics principles.

Checks for Understanding (Formative/Summative Assessment)

- ✓3231.Math.1 Plot points on the Cartesian coordinate graphing system.
- ✓3231.Math.2 Graph basic relations and functions.
- ✓3231.Math.3 Determine the slope of a linear function.
- ✓3231.Math.4 Determine the frequency, range, mode, median, and mean from a data set.
- ✓3231.Math.5 Utilize a graphing calculator to enter data and find basic statistics: frequency, range, means, mode, median, and standard deviation.
- ✓3231.Math.6 Solve for all variables based on a formula.
- ✓3231.Math.7 Solve for the t – value, p (probability), and % of confidence between two lists of data (manipulated variables and responding variables).

- ✓3231.Math.8 Reject or accept a null hypothesis based on statistical analysis.
- ✓3231.Math.9 Find the regression line (equation) between data for manipulated and responding variables.
- ✓3231.Math.10 Utilize trigonometric functions (sine, cosine, and tangent) to solve simple vector problems.
- ✓3231.Math.11 Apply the laws of sine and cosine to solve vector problems.
- ✓3231.Math.12 Solve mechanics problems using the quadratic formula.
- ✓3231.Math.13 Find the derivative (velocity function) of a distance (displacement) function.
- ✓3231.Math.14 Find the derivative (acceleration function) of a velocity function.
- ✓3231.Math.15 Link various calculus procedures to solve physics problems.

Standard 1 – Mechanics

Conceptual Strand 1

Laws and properties of mechanics are the foundations of physics.

Guiding Question 1

How do the laws and properties of mechanics govern the basic understanding of physics.

Course Level Expectations

- CLE 3231.1.1 Investigate fundamental physical quantities of mass and time.
- CLE 3231.1.2 Analyze and apply Newton's three laws of motion.
- CLE 3231.1.3 Understand work, energy, and power.
- CLE 3231.1.4 Investigate kinematics and dynamics.
- CLE 3231.1.5 Investigate and apply Archimedes's Principle.
- CLE 3231.1.6 Explore Pascal's Principle.
- CLE 3231.1.7 Analyze applications of Bernoulli's Principle.

Checks for Understanding (Formative/Summative Assessment)

- ✓3231.1.1 Explore displacement, velocity, and acceleration [Average Velocity: $v_{av} = (d_f - d_i) / (t_f - t_i)$; Final Velocity: $v_f = v_i + a\Delta t$; Final Velocity of Falling: $v_f = v_i + g\Delta t$; Average Acceleration: $a_{av} = (v_f - v_i) / (t_f - t_i)$; Displacement: $d = v_i \Delta t + (1/2) a\Delta t^2$; Displacement of Falling: $\Delta d = v_i \Delta t + (1/2)g \Delta t^2$].
- ✓3231.1.2 Analyze vector diagrams and solve composition and resolution problems for force and momentum.
- ✓3231.1.3 Explore characteristics of rectilinear motion and create distance-time graphs (velocity), velocity-time graphs (acceleration and distance).
- ✓3231.1.4 Investigate the characteristics of centripetal motion and centripetal acceleration [Centripetal Force: $F_c = (mv^2)/r$; Angular Velocity: $\omega = \Delta \theta / \Delta t$; Angular Acceleration: $\alpha = \Delta \omega / \Delta t$].
- ✓3231.1.5 Evaluate the dynamics of systems in motion including friction, gravity, impulse and momentum, change in momentum, and conservation of momentum. [Coefficient of Friction: $\mu = F_f / F_N$; Law of Universal Gravitation: $F_G = (G m_1 m_2) / d^2$; Impulse and Change of Momentum: $F \Delta t = m\Delta t$].

- ✓3231.1.6 Investigate projectile motion. [Parabolic Equations with Quadratic Formula:

$$X = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

- ✓3231.1.7 Apply mathematics to solve motion problems.
- ✓3231.1.8 Experiment with elastic and inelastic collisions.
- ✓3231.1.9 Experiment with pendulums [Pendulum period: $T = 2\pi \sqrt{l/g}$].
- ✓3231.1.10 Utilize trigonometry and vector analysis to solve force and momentum problems [Sine, Cosine, Tangent Functions, Law of Sine, and Law of Cosine].
- ✓3231.1.11 Apply elementary calculus to solve motion problems [Velocity = derivative of and acceleration = derivative of velocity].
- ✓3231.1.12 Experiment with elastic and inelastic collisions [Elastic Collisions in One Dimension: $m_1v_1 + m_2v_2 = m_1v_3 + m_2v_4$; Inelastic Collision in One Dimension: $m_1v_1 + m_2v_2 = (m_1 + m_2)v_3$].
- ✓3231.1.13 Distinguish between mass and weight using base units in the SI system.
- ✓3231.1.14 Associate time with the independent variable in most experiments.
- ✓3231.1.15 Relate inertia, force or action-reaction forces to Newton's three laws of motion.
- ✓3231.1.16 Compare, contrast, and apply characteristic properties of scalar and vector quantities.
- ✓3231.1.17 Investigate the definitions of force, work, power, kinetic energy, and potential energy. [Force: $F = ma$; Work: $W = Fd$; Power: $P = (F\Delta d)/\Delta t$; Kinetic Energy: $E_K = 0.5mv^2$; Potential Energy: $E_P = mg\Delta h$].
- ✓3231.1.18 Analyze the characteristics of energy, conservation of energy including friction, and gravitational potential energy [Gravitational Potential Energy: $E_p = mg\Delta h$].
- ✓3231.1.19 Relate work and power to various simple machines, mechanical advantage of different machines, and recognize simple machines that are combined to form compound machines [Work: $W = F\Delta d$; Power: $p = (F\Delta d)/\Delta t$; Efficiency, Efficiency = $(W_{OUT}/W_{IN}) \times 100\%$].
- ✓3231.1.20 Describe rotational equilibrium and relate this factor to torque [Rotational Inertia: $T = I\alpha$; Torque: $T = Fr$].
- ✓3231.1.21 Determine the magnitude of the buoyant force exerted on floating and submerged objects ($F_B = m_f g = \rho_f V_f g$).
- ✓3231.1.22 Investigate the apparent weight of an object submerged in a fluid ($F_{net} = F_B - F_g$).
- ✓3231.1.23 Explain why objects float or sink in terms of force and density.
- ✓3231.1.24 Calculate the pressure exerted by a fluid according to Pascal's Principle ($P_{inc} = F_1/A_1 = F_2/A_2$).
- ✓3231.1.25 Calculate how pressure varies with depth ($P = P_0 + \rho gh$).
- ✓3231.1.26 Examine the motion of a fluid using the continuity equation ($A_1v_1 = A_2v_2$).
- ✓3231.1.27 Recognize the effects of Bernoulli's principle on fluid motion (e.g., lift, ball trajectories, and wind around/over object).

Standard 2 – Thermodynamics

Conceptual Strand 2

The principles and laws of thermodynamics explain the concepts of energy.

Guiding Question 2

How do the laws of thermodynamics relate to the conservation of energy?

Course Level Expectations

- CLE 3231.2.1 Develop a deep understanding of heat and internal energy.
- CLE 3231.2.2 Compare Celsius, Kelvin and the Absolute temperature scales.
- CLE 3231.2.3 Investigate exchanges in internal energy.

Checks for Understanding (Formative/Summative Assessment)

- ✓3231.2.1 Investigate temperature in relationship to kinetic energy.
- ✓3231.2.2 Identify the characteristics of internal energy and temperature/heat (joules/calories).
- ✓3231.2.3 Investigate changes in heat content (quantity of thermal energy) and relate to kinetic energy and specific heat.
- ✓3231.2.4 Investigate potential energy changes (phase changes) of heat of fusion, heat of vaporization, and heat of sublimation [Change in Heat: $\Delta Q = mH_v$ and $\Delta Q = mH_v$].
- ✓3231.2.5 Explore thermal expansion and contraction [Linear Expansion: $\Delta l = l_i \alpha \Delta T$; Volumetric Expansion: $\Delta V = V_i \beta \Delta T$].
- ✓3231.2.6 Apply the second law of thermodynamics to the Carnot engine.
- ✓3231.2.7 Apply the Laws of Thermodynamics to the atmospheric levels of the earth (i.e., greenhouse effect and global warming).
- ✓3231.2.8 Recognize that absolute zero is the absence of molecular kinetic energy.
- ✓3231.2.9 Relate the First Law of Thermodynamics as an application of the Law of Conservation of Energy and heat transfer through conduction, convection, and radiation. [Heat Lost = Heat Gained, $Q_L = Q_G$].
- ✓3231.2.10 Relate change in heat content (quantity of thermal energy) to kinetic energy and specific heat [Change in Heat: $\Delta Q = mC\Delta T$].

Standard 3 – Waves

Conceptual Strand 3

Investigating wave behavior reveals information about sound and light.

Guiding Question 3

How do the properties of mechanical waves, sound, and light explain the behavior of waves?

Course Level Expectations

- CLE 3231.3.1 Explore conditions associated with simple harmonic motion.
- CLE 3231.3.2 Investigate Hooke's law.

- CLE 3231.3.3 Understand wave mechanics.
- CLE 3231.3.4 Examine the Doppler Effect.
- CLE 3231.3.5 Explore the characteristics and properties of sound.

Checks for Understanding (Formative/Summative Assessment)

- ✓3231.3.1 Investigate simple harmonic motion.
- ✓3231.3.2 Investigate and analyze wavelength, frequency, and amplitude of longitudinal and transverse waves.
- ✓3231.3.3 Describe a wave interaction as reflection, refraction, diffraction, or interference.
- ✓3231.3.4 Explore Hooke's Law.
- ✓3231.3.5 Investigate reflection, refraction, diffraction, and interference of sound waves.
- ✓3231.3.6 Compare mechanical and electromagnetic waves.
- ✓3231.3.7 Explain the Doppler Effect.

Source moving toward stationary listener:

$$f_{LF} = f_s \frac{v}{v - v_s}$$

Source moving away from stationary listener:

$$f_{LB} = f_s \frac{v}{v + v_s}$$

Listener moving toward stationary source:

$$f_{LC} = f_s \frac{v + v_{LC}}{v}$$

Listener moving away from stationary source:

$$f_{LO} = f_s \frac{v - v_{LO}}{v}$$

- ✓3231.3.8 Determine the speed of sound experimentally and describe the effects various materials and temperatures on sound transmission.
- ✓3231.3.9 Measure spring constants.
- ✓3231.3.10 Solve problems related to wave length, frequency and speed [wave velocity: $v = f\lambda$].
- ✓3231.3.11 Determine the speed of sound experimentally using various materials and temperatures [sound velocity: $v_s = f\lambda$; Sound velocity (using air temperature): $v_s = 331.5\text{m/s} + (0.56 \text{ m/s } ^\circ\text{C}) (T)$].
- ✓3231.3.12 Describe simple harmonic motion.
- ✓3231.3.13 Compare the wave characteristics of natural auditory phenomena.

Standard 4 – Optics

Conceptual Strand 4

Understanding optics is accomplished by investigating the behavior and laws of light.

Guiding Question 4

How do the properties and behavior of light relate to the basic principles of optics?

Course Level Expectations

- CLE 3231.4.1 Describe the characteristics of the electromagnetic spectrum.
- CLE 3231.4.2 Investigate the interaction of light waves.
- CLE 3231.4.3 Explore the optics of lenses.
- CLE 3231.4.4 Analyze the optics of mirrors.
- CLE 3231.4.5 Investigate the phenomenon of color.

Checks for Understanding (Formative/Summative Assessment)

- ✓3231.4.1 Explore properties of electromagnetic radiation.
- ✓3231.4.2 Examine properties of light waves.
- ✓3231.4.3 Investigate the polarization of light.
- ✓3231.4.4 Investigate the optical properties of plane and curved mirrors [Focal length: $1/f = 1/d_o + 1/d_i$; Images in mirrors and lens, $h_i/h_o = d_i/d_o$].
- ✓3231.4.5 Investigate the optical properties of plane and curved mirrors.
- ✓3231.4.6 Draw, explain, and solve problems for the optics of mirrors and lenses.
- ✓3231.4.7 Investigate optical phenomena (i.e., mirage, optical illusions, and dichromatic lens effect).
- ✓3231.4.8 Solve problems related to Snell's law [Index of refraction: $n = (\sin \theta_r / \sin \theta_i)$; Snell's law: $n_i \sin \theta_i = n_r \sin \theta_r$].
- ✓3231.4.9 Differentiate among transmission, reflection, refraction, diffraction, and interference of light waves.
- ✓3231.4.10 Explore the formation of color (both additive and subtractive properties) [Additive Color Theory: $W = B + G + R$; $Y = G + R$; $C = B + G$; $M = R + B$; Subtractive Color Theory: $B = W - Y$; $C = W - R$; $M = W - G$].

Standard 5 – Electricity and Magnetism

Conceptual Strand 5

Understanding electricity and magnetism is explained by the physics of electrons and magnets.

Guiding Question 5

How do the properties of electricity and magnetism relate to the physics of electrons and magnets?

Course Level Expectations

- CLE 3231.5.1 Examine the properties of electric forces, electric charges, and electric fields.
- CLE 3231.5.2 Explore the flow of charge and electric currents.
- CLE 3231.5.3 Investigate Ohm's law.
- CLE 3231.5.4 Compare and contrast series and parallel circuits.
- CLE 3231.5.5 Analyze components of electrical schematic diagrams.
- CLE 3231.5.6 Understand magnetic poles, magnetic fields, and investigate electromagnetic induction.

Checks for Understanding (Formative/Summative Assessment)

- ✓3231.5.1 Create a simple electromagnet.
- ✓3231.5.2 Draw an electric field based on a description of the charged particles.
- ✓3231.5.3 Solve problems of resistance using Ohm's law [$E = IR$ (or $V=IR$)].
- ✓3231.5.4 Draw and explain series and parallel circuits.
- ✓3231.5.5 Solve problems related to voltage, amperage, and resistance [voltage, $V = IR$; series circuit formulas, $R_T = R_1 + R_2 + \dots$, $I_T = I_1 = I_2 = \dots$, $V_T = V_1 + V_2 + \dots$; parallel circuit formulas, $1/R_T = 1/R_1 + 1/R_2 + \dots$, $I_T = I_1 + I_2 + \dots$, $V_T = V_1 = V_2 = \dots$].
- ✓3231.5.6 Build series and parallel circuits and explain how they function.
- ✓3231.5.7 Demonstrate a generated current by electromagnetic induction.
- ✓3231.5.8 Design an experiment to demonstrate the flow of charged particles and an electric current.
- ✓3231.5.9 Analyze a group of charges for repulsion and attraction.
- ✓3231.5.10 Distinguish between charged particles related to repulsion and attraction.
- ✓3231.5.11 Describe the electric field that fills the space around a charged particle or group of charges [Coulomb's law of electrostatics, $F = k(Q_1Q_2)/d^2$].
- ✓3231.5.12 Identify components of series and parallel circuits and solve problems related to voltage, amperage, and resistance.
- ✓3231.5.13 Describe how current is generated by electromagnetic induction.

Standard 6 – Nuclear Physics

Conceptual Strand 6

A deep understanding of particle physics is accomplished by investigating the properties of nuclear physics.

Guiding Question 6

How is the investigation of the properties of nuclear physics related to understanding nuclear particles?

Course Level Expectations

- CLE 3231.6.1 Investigate the properties and structure of the atom.
- CLE 3231.6.2 Compare and contrast the Bohr model and the quantum model of the atom.
- CLE 3231.6.3 Explore the dynamics of the nucleus: radioactivity, nuclear decay, radiocarbon/uranium dating and half-life.
- CLE 3231.6.4 Compare and contrast nuclear fission and nuclear fusion.
- CLE 3231.6.5 Investigate the quantum theory.

Checks for Understanding (Formative/Summative Assessment)

- ✓3231.6.1 Write and balance equations for the three forms of radioactive decay.
- ✓3231.6.2 Solve half-life problems [decay constant: $k=0.693/T_{(1/2)}$; nuclear decay: $A_f = A_0e^{-kt}$].
- ✓3231.6.3 Explain dating methods using carbon-14 or uranium.
- ✓3231.6.4 Investigate the concept of half-life.
- ✓3231.6.5 Explain how particles behave like waves.
- ✓3231.6.6 Distinguish between coherent and incoherent light.

- ✓3231.6.7 Recognize how the quantum theory explains the photoelectric effect.
- ✓3231.6.8 Investigate the history and current events associated with nuclear and radioactive science.
- ✓3231.6.9 Identify the parts of an atom.
- ✓3231.6.10 Describe the properties and location of subatomic particles.
- ✓3231.6.11 Describe three forms of radioactivity.
- ✓3231.6.12 Distinguish between nuclear fission and nuclear fusion.
- ✓3231.6.13 Distinguish between the Bohr model and the quantum model of an atom.
- ✓3231.6.14 Explain the changes in atomic number or mass number for each form of radioactivity.
- ✓3231.6.15 Discuss transmutation and transuranium.
- ✓3231.6.16 Explain how particles behave like waves.
- ✓3231.6.17 Examine the properties of lasers.
- ✓3231.6.18 Recognize how the quantum theory explains the photoelectric effect.

Tennessee Science Curriculum Framework

Chemistry I

Course Description

Chemistry is a laboratory course in which students study the composition of matter and the physical and chemical changes it undergoes. In this course, students use science process skills to investigate the fundamental structure of atoms, the way atoms combine to form compounds, and the interactions between matter and energy. Students explore chemistry concepts through an inquiry approach.

Chemistry students investigate:

- Inquiry
- Technology and Engineering
- Atomic Structure
- Matter and Energy
- Interactions of Matter

Embedded Inquiry

Embedded Conceptual Strand

Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21st century.

Guiding Question

What tools, skills, knowledge, and dispositions are needed to conduct scientific inquiry?

Course Level Expectations

CLE 3221.Inq.1 Recognize that science is a progressive endeavor that reevaluates and extends what is already accepted.

CLE 3221.Inq.2 Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.

CLE 3221.Inq.3 Use appropriate tools and technology to collect precise and accurate data.

CLE 3221.Inq.4 Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.

CLE 3221.Inq.5 Compare experimental evidence and conclusions with those drawn by others.

CLE 3221.Inq.6 Communicate and defend scientific findings.

Checks for Understanding (Formative/Summative Assessment)

- ✓3221.Inq.1 Trace the historical development of a scientific principle or theory.
- ✓3221.Inq.2 Identify an answerable question and formulate a hypothesis to guide a scientific investigation.
- ✓3221.Inq.3 Design a simple experiment including appropriate controls.
- ✓3221.Inq.4 Perform and understand laboratory procedures directed at testing hypothesis.
- ✓3221.Inq.5 Select appropriate tools and technology to collect precise and accurate quantitative and qualitative data.
- ✓3221.Inq.6 Correctly read a thermometer, balance, metric ruler, graduated cylinder, pipette, and burette.
- ✓3221.Inq.7 Record observations and/or data using correct scientific units and significant figures.
- ✓3221.Inq.8 Export data into the appropriate form of data presentation (e.g., equation, table, graph, or diagram).
- ✓3221.Inq.9 Translate data into the correct units and dimension using conversion factors and scientific notation.
- ✓3221.Inq.10 Analyze information in a table, graph or diagram (e.g., compute the mean of a series of values or determine the slope of a line).
- ✓3221.Inq.11 If accepted values are known, calculate the percent error for an experiment.
- ✓3221.Inq.12 Determine the accuracy and precision of experimental results.
- ✓3221.Inq.13 Analyze experimental results and identify possible sources of bias or experimental error.
- ✓3221.Inq.14 Recognize, analyze, and evaluate alternative explanations for the same set of observations.
- ✓3221.Inq.15 Design a model based on the correct hypothesis that can be used for further investigation.

State Performance Indicators

- SPI 3221 Inq.1 Select a description or scenario that reevaluates and/or extends a scientific finding.
- SPI 3221 Inq.2 Analyze the components of a properly designed scientific investigation.
- SPI 3221 Inq.3 Determine appropriate tools to gather precise and accurate data.
- SPI 3221 Inq.4 Evaluate the accuracy and precision of data.
- SPI 3221 Inq.5 Defend a conclusion based on scientific evidence.
- SPI 3221 Inq.6 Determine why a conclusion is free of bias.
- SPI 3221 Inq.7 Compare conclusions that offer different, but acceptable explanations for the same set of experimental data.

Embedded Technology and Engineering

Conceptual Strand

Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.

Guiding Question

How do science concepts, engineering skills, and applications of technology improve the quality of life?

Course Level Expectations

- CLE 3221.T/E.1 Explore the impact of technology on social, political, and economic systems.
- CLE 3221.T/E.2 Differentiate among elements of the engineering design cycle: design constraints, model building, testing, evaluating, modifying, and retesting.
- CLE 3221.T/E.3 Explain the relationship between the properties of a material and the use of the material in the application of a technology.
- CLE 3221.T/E.4 Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems.

Checks for Understanding (Formative/Summative Assessment)

- ✓3221.1 Select appropriate tools to conduct a scientific inquiry.
- ✓3221.2 Apply the engineering design process to construct a prototype that meets developmentally appropriate specifications.
- ✓3221.3 Explore how the unintended consequences of new technologies can impact human and non-human communities.
- ✓3221.4 Present research on current bioengineering technologies that advance health and contribute to improvements in our daily lives.
- ✓3221.5 Design a series of multi-view drawings that can be used by other students to construct an adaptive design and test its effectiveness.

State Performance Indicators

- SPI 3221.T/E.1 Distinguish among tools and procedures best suited to conduct a specified scientific inquiry.
- SPI 3221.T/E.2 Evaluate a protocol to determine the degree to which an engineering design process was successfully applied.
- SPI 3221.T/E.3 Evaluate the overall benefit to cost ratio of a new technology.
- SPI 3221.T/E.4 Use design principles to determine if a new technology will improve the quality of life for an intended audience.

Embedded Mathematics

Conceptual Strand

Science applies mathematics to investigate questions, solve problems, and communicate findings.

Guiding Question

What mathematical skills and understandings are needed to successfully investigate chemistry?

Course Level Expectations

- CLE 3221.Math.1 Understand the mathematical principles associated with the science of chemistry.
- CLE 3221.Math.2 Utilize appropriate mathematical equations and processes to solve chemistry problems.

Checks for Understanding (Formative/Summative Assessment)

- ✓3221.Math.1 Use a variety of appropriate notations (e.g., exponential, functional, square root).
- ✓3221.Math.2 Select and apply appropriate methods for computing with real numbers and evaluate the reasonableness of the results.
- ✓3221.Math.3 Apply algebraic properties, formulas, and relationships to perform operations on real-world problems (e.g., solve for density, determine the concentration of a solution in a variety of units: ppm, ppb, molarity, molality, and percent composition) calculate heats of reactions and phase changes, and manipulate gas law equations.
- ✓3221.Math.4 Interpret rates of change from graphical and numerical data (e.g., phase diagrams, solubility graphs, colligative properties, nuclear decay or half-life).
- ✓3221.Math.5 Analyze graphs to describe the behavior of functions (e.g., concentration of a solution, phase diagrams, solubility graphs, colligative properties, nuclear decay half-life).
- ✓3221.Math.6 Model real-world phenomena using functions and graphs.
- ✓3221.Math.7 Apply and interpret algebraic properties in symbolic manipulation (e.g., density, concentration of a solution, chemical equations, effect of volume, temperature or pressure on behavior of a gas, percent composition of elements in a compound, molar mass, number of moles, and molar volume, amount of products or reactants given mole, molarity, volume at STP or mass amounts, heat loss or gain using mass, temperature change and specific heat, and half-life of an isotope).
- ✓3221.Math.8 Apply and communicate measurement units, concepts and relationships in algebraic problem-solving situations.
- ✓3221.Math.9 Select appropriate units, scales, and measurement tools for problem situations involving proportional reasoning and dimensional analysis.
- ✓3221.Math.10 Select, construct, and analyze appropriate graphical representations for a data set.
- ✓3221.Math.11 Identify and solve different types of stoichiometry problems (e.g., volume at STP to mass, moles to mass, molarity).
- ✓3221.Math.12 Calculate the amount of product expected in an experiment and determine percent yield.
- ✓3221.Math.13 Convert among the quantities of a substance: mass, number of moles, number of particles, molar volume at STP.

State Performance Indicators

- SPI 3221.Math.1 Use real numbers to represent real-world applications (e.g., slope, rate of change, probability, and proportionality).

- SPI 3221.Math.2 Perform operations on algebraic expressions and informally justify the selected procedures.
- SPI 3221.Math.3 Interpret graphs that depict real-world phenomena.
- SPI 3221.Math.4 Apply measurement unit relationships including Avogadro's number, molarity, molality, volume, and mass to balance chemical equations.
- SPI 3221.Math.5 Use concepts of mass, length, area, and volume to estimate and solve real-world problems.

Standard 1 – Atomic Structure

Conceptual Strand 1

Atomic theory is the foundation for understanding the interactions and changes in matter.

Guiding Question 1

How does the structure of matter determine its chemical and physical properties?

Course Level Expectations

- CLE 3221.1.1 Compare and contrast historical models of the atom.
- CLE 3221.1.2 Analyze the organization of the modern periodic table.
- CLE 3221.1.3 Describe an atom in terms of its composition and electron characteristics.

Checks for Understanding (Formative/Summative Assessment)

- ✓3221.1.1 Identify the contributions of major atomic theorists: Bohr, Chadwick, Dalton, Planck, Rutherford, and Thomson.
- ✓3221.1.2 Compare the Bohr model and the quantum mechanical electron-cloud models of the atom.
- ✓3221.1.3 Draw Bohr models of the first 18 elements.
- ✓3221.1.4 Interpret a Bohr model of an electron moving between its ground and excited states in terms of the absorption or emission of energy.
- ✓3221.1.5 Use the periodic table to identify an element as a metal, nonmetal, or metalloid.
- ✓3221.1.6 Apply the periodic table to determine the number of protons and electrons in a neutral atom.
- ✓3221.1.7 Determine the number of protons and neutrons for a particular isotope of an element.
- ✓3221.1.8 Explain the formation of anions and cations, and predict the charge of an ion formed by the main-group elements.
- ✓3221.1.9 Sequence selected atoms from the main-group elements based on their atomic or ionic radii.
- ✓3221.1.10 Sequence selected atoms from the main-group elements based on first ionization energy, electron affinity, or electronegativity.
- ✓3221.1.11 Determine an atom's Lewis electron-dot structure or number of valence electrons from an element's atomic number or position in the periodic table.
- ✓3221.1.12 Represent an atom's electron arrangement in terms of orbital notation, electron configuration notation, and electron-dot notation.

- ✓3221.1.13 Compare s and p orbitals in terms of their shape, and order the s, p, d and f orbitals in terms of energy and number of possible electrons.

State Performance Indicators

- SPI 3221.1.1 Compare and contrast the major models of the atom (e.g., Democritus, Thomson, Rutherford, Bohr, and the quantum mechanical model).
- SPI 3221.1.2 Interpret the periodic table to describe an element's atomic makeup.
- SPI 3221.1.3 Describe the trends found in the periodic table with respect to atomic size, ionization energy, electron affinity, or electronegativity.
- SPI 3221.1.4 Determine the Lewis electron-dot structure or number of valence electrons for an atom of any main-group element from its atomic number or position in the periodic table.
- SPI 3221.1.5 Represent an electron's location in the quantum mechanical model of an atom in terms of the shape of electron clouds (s and p orbitals in particular), relative energies of orbitals, and the number of electrons possible in the s, p, d and f orbitals.

Standard 2 – Matter and Energy

Conceptual Strand 2

The properties of matter determine how it interacts with energy.

Guiding Question 2

What is the relationship between matter and energy?

Course Level Expectations

- CLE 3221.2.1 Investigate the characteristic properties of matter.
- CLE 3221.2.2 Explore the interactions between matter and energy.
- CLE 3221.2.3 Apply the kinetic molecular theory to describe solids, liquids, and gases.
- CLE 3221.2.4 Investigate characteristics associated with the gaseous state.
- CLE 3221.2.5 Discuss phase diagrams of one-component systems.

Checks for Understanding (Formative/Summative Assessment)

- ✓3221.2.1 Identify a material as an element, compound or mixture; identify a mixture as homogeneous or heterogeneous; and/or identify a mixture as a solution, colloid or suspension.
- ✓3221.2.2 Identify the solute and solvent composition of a solid, liquid or gaseous solution.
- ✓3221.2.3 Express the concentration of a solution in units of ppm, ppb, molarity, molality, and percent composition.
- ✓3221.2.4 Describe how to prepare solutions of given concentrations expressed in units of ppm, ppb, molarity, molality, and percent composition.
- ✓3221.2.5 Investigate factors that affect the rate of solution.
- ✓3221.2.6 Describe how to prepare a specific dilution from a solution of known molarity.

- ✓3221.2.7 Determine the colligative properties of a solution based on the molality and freezing point or boiling points of the solvent.
- ✓3221.2.8 Use a solubility graph, composition of a solution and temperature to determine if a solution is saturated, unsaturated or supersaturated.
- ✓3221.2.9 Classify properties and changes in matter as physical, chemical, or nuclear.
- ✓3221.10 Use calorimetry to: identify unknown substances through specific heat, determine the heat changes in physical and chemical changes, determine the mass of an object, and determine the change in temperature of a material.
- ✓3221.2.11 Perform calculations on heat of solvation, heat of reaction, and heat of formation, and heat of phase change.
- ✓3221.2.12 Use particle spacing diagrams to identify solids, liquids, or gases.
- ✓3221.2.13 Distinguish among solid, liquid, and gaseous states of a substance in terms of the relative kinetic energy of its particles.
- ✓3221.2.14 Use a phase diagram to correlate changes in temperature and energy with phases of matter.
- ✓3221.2.15 Graph and interpret the results of experiments that explore relationships among pressure, temperature, and volume of gases.
- ✓3221.2.16 Solve gas law problems.

State Performance Indicators

- SPI 3221.2.1 Distinguish among elements, compounds, solutions, colloids, and suspensions.
- SPI 3221.2.2 Identify properties of a solution: solute and solvent in a solid, liquid or gaseous solution; procedure to make or determine the concentration of a solution in units of ppm, ppb, molarity, molality, percent composition, factors that affect the rate of solution, and colligative properties.
- SPI 3221.2.3 Classify a solution as saturated, unsaturated, or supersaturated based on its composition and temperature and a solubility graph.
- SPI 3221.2.4 Classify a property of change in matter as physical, chemical, or nuclear.
- SPI 3221.2.5 Compare and contrast heat and temperature changes in chemical and physical processes.
- SPI 3221.2.6 Investigate similarities and differences among solids, liquids and gases in terms of energy and particle spacing.
- SPI 3221.2.7 Predict how changes in volume, temperature, and pressure affect the behavior of a gas.

Standard 3 – Interactions of Matter

Conceptual Strand 3

Interactions between matter generate substances with new physical and chemical properties.

Guiding Question 3

What types of interactions between matter generate new substances?

Course Level Expectations

- CLE 3221.3.1 Investigate chemical bonding.
- CLE 3221.3.2 Analyze chemical and nuclear reactions.
- CLE 3221.3.3 Explore the mathematics of chemical formulas and equations.
- CLE 3221.3.4 Explain the law of conservation of mass/energy.

Checks for Understanding (Formative/Summative Assessment)

- ✓3221.3.1 Determine the type of chemical bond that occurs in a chemical compound.
- ✓3221.3.2 Differentiate between ionic and covalent bond models.
- ✓3221.3.3 Identify the chemical formulas of common chemical compounds.
- ✓3221.3.4 Employ a table of polyvalent cations and polyatomic ions to name and describe the chemical formula of ionic compounds.
- ✓3221.3.5 Convert percent composition information into the empirical or molecular formula of a compound.
- ✓3221.3.6 Apply information about the molar mass, number of moles, and molar volume to the number of particles of the substance.
- ✓3221.3.7 Balance an equation for a chemical reaction.
- ✓3221.3.8 Classify a chemical reaction as composition, decomposition, single replacement, double replacement, and combustion.
- ✓3221.3.9 Use activity series or solubility product table information to predict the products of a chemical reaction.
- ✓3221.3.10 Predict the products of a neutralization reaction involving inorganic acids and bases.
- ✓3221.3.11 Interpret a chemical equation to determine molar ratios.
- ✓3221.3.12 Convert between the following quantities of a substance: mass, number of moles, number of particles, and molar volume at STP.
- ✓3221.3.13 Solve different types of stoichiometry problems (e.g., volume at STP to mass, moles to mass, molarity,).
- ✓3221.3.14 Determine the amount of expected product in an experiment and calculate percent yield.
- ✓3221.3.15 Calculate the amount of heat lost or gained by a substance based on its mass, change in temperature, and specific heat during physical and chemical processes.
- ✓3221.3.16 Research applications of thermal changes in nuclear reactions.
- ✓3221.3.17 Identify a substance as an acid or base according to its formula.
- ✓3221.3.18 Investigate the acidity/basicity of substances with various indicators.
- ✓3221.3.19 Write the nuclear equation involving alpha or beta particles based on the mass number of the parent isotope and complete symbols for alpha or beta emissions.
- ✓3221.3.20 Determine the half-life of an isotope by examining a graph or with an appropriate equation.
- ✓3221.3.21 Write a balanced nuclear equation to compare nuclear fusion and fission.
- ✓3221.3.22 Describe the benefits and hazards of nuclear energy.

State Performance Indicators

- SPI 3221.3.1 Analyze ionic and covalent compounds in terms of how they form, names, chemical formulas, percent composition, and molar masses.

- SPI 3221.3.2 Identify the reactants, products, and types of different chemical reactions: composition, decomposition, double replacement, single replacement, combustion.
- SPI 3221.3.3 Predict the products of a chemical reaction.
- SPI 3221.3.4 Balance a chemical equation to determine molar ratios.
- SPI 3221.3.5 Convert among the following quantities of a substance: mass, number of moles, number of particles, molar volume at STP.
- SPI 3221.3.6 Identify and solve stoichiometry problems: volume at STP to mass, moles to mass, and molarity.
- SPI 3221.3.7 Classify substances as acids or bases based on their formulas and how they react with various indicators.
- SPI 3221.3.8 Describe radioactive decay through a balanced nuclear equation and through an analysis of the half-life concept.
- SPI 3221.3.9 Compare and contrast nuclear fission and fusion.
- SPI 3221.3.10 Relate the laws of conservation of mass/energy to thermal changes that occur during physical, chemical or nuclear processes.

Tennessee Science Curriculum Framework

Chemistry II

Course Description

Chemistry II is a laboratory course that builds on topics taught in Chemistry I. This course investigates chemical bonding and how the kinetic molecular theory and by intermolecular forces explain the physical and chemical characteristics of matter. Additional aspects of chemical reactions including limiting reactants, percent yield, equilibrium, reaction rates, and thermochemistry are considered. Students explore chemistry concepts through an inquiry approach.

Chemistry II students investigate:

- Inquiry
- Technology and Engineering
- Structure of Matter
- States of Matter
- Reactions

Embedded Inquiry

Conceptual Strand

Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21st century.

Guiding Question

What tools, skills, knowledge, and dispositions are needed to conduct scientific inquiry?

Course Level Expectations

- CLE 3222.Inq.1** Recognize that science is a progressive endeavor that reevaluates and extends what is already accepted.
- CLE 3222.Inq.2** Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.
- CLE 3222.Inq.3** Use appropriate tools and technology to collect precise and accurate data.
- CLE 3222.Inq.4** Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.
- CLE 3222.Inq.5** Compare experimental evidence and conclusions with those drawn by others about the same testable question.
- CLE 3222.Inq.6** Communicate and defend scientific findings.

Checks for Understanding (Formative/Summative Assessment)

- ✓**3222.Inq.1** Trace the historical development of a scientific principle or theory.

- ✓ **3222.Inq.2** Identify an answerable question and formulate a hypothesis to guide a scientific investigation.
- ✓ **3222.Inq.3** Design a simple experiment including appropriate controls.
- ✓ **3222.Inq.4** Perform and understand laboratory procedures directed at testing hypothesis.
- ✓ **3222.Inq.5** Select appropriate tools and technology to collect precise and accurate quantitative and qualitative data.
- ✓ **3222.Inq.6** Correctly read a thermometer, balance, metric ruler, graduated cylinder, pipette, and burette.
- ✓ **3222.Inq.7** Record observations and/or data using correct scientific units and significant figures.
- ✓ **3222.Inq.8** Export data into the appropriate form of data presentation (e.g., equation, table, graph, or diagram).
- ✓ **3222.Inq.9** Translate data into the correct units and dimension using conversion factors and scientific notation.
- ✓ **3222.Inq.10** Analyze information in a table, graph or diagram (e.g., compute the mean of a series of values or determine the slope of a line).
- ✓ **3222.Inq.11** If accepted values are known, calculate the percent error for an experiment.
- ✓ **3222.Inq.12** Determine the accuracy and precision of experimental results.
- ✓ **3222.Inq.13** Analyze experimental results and identify possible sources of bias or experimental error.
- ✓ **3222.Inq.14** Recognize, analyze, and evaluate alternative explanations for the same set of observations.
- ✓ **3222.Inq.15** Design a model based on the correct hypothesis that can be used for further investigation.

Embedded Technology and Engineering

Conceptual Strand

Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.

Guiding Question

How do science concepts, engineering skills, and applications of technology improve the quality of life?

Course Level Expectations

- CLE 3222.T/E.1** Explore the impact of technology on social, political, and economic systems.
- CLE 3222.T/E.2** Differentiate among elements of the engineering design cycle: design constraints, model building, testing, evaluating, modifying, and retesting.
- CLE 3222.T/E.3** Explain the relationship between the properties of a material and the use of the material in the application of a technology.
- CLE 3222.T/E.4** Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems.

Checks for Understanding (Formative/Summative Assessment)

- ✓3222.T/E.1 Distinguish among tools and procedures best suited to conduct a specified scientific inquiry.
- ✓3222.T/E.2 Apply the engineering design process to construct a prototype that meets developmentally appropriate specifications.
- ✓3222.T/E.3 Evaluate a protocol to determine the degree to which an engineering design process was successfully applied.
- ✓3222.T/E.4 Explore how the unintended consequences of new technologies can impact human and non-human communities.
- ✓3222.T/E.5 Evaluate the overall benefit to cost ratio of a new technology.
- ✓3222.T/E.6 Present research on current bioengineering technologies that advance health and contribute to improvements in our daily lives.
- ✓3222.T/E.7 Design a series of multi-view drawings that can be used by other students to construct an adaptive design and test its effectiveness.

Embedded Mathematics

Conceptual Strand

Science applies mathematics to investigate questions, solve problems, and communicate findings.

Guiding Question

What mathematical skills and understandings are needed to successfully investigate chemistry?

Course Level Expectations

- CLE 3222.Math.1** Understand the mathematical principles associated with the science of chemistry.
- CLE 3222.Math.2** Utilize appropriate mathematical equations and processes to solve chemistry problems.

Checks for Understanding (Formative/Summative Assessment)

- ✓3222.Math.1 Use a variety of appropriate notations (e.g., exponential, functional, square root).
- ✓3222.Math.2 Select and apply appropriate methods for computing with real numbers and evaluate the reasonableness of the results.
- ✓3222.Math.3 Apply algebraic properties, formulas, and relationships to perform operations on real-world problems such as: solving for density, determining the concentration of a solution in a variety of units (e.g., ppm, ppb, molarity, molality, and percent composition), calculating heats of reactions and phase changes, and manipulating gas law equations.
- ✓3222.Math.4 Interpret rates of change from graphical and numerical data (e.g., phase diagrams, solubility graphs, colligative properties, nuclear decay or half-life).
- ✓3222.Math.5 Analyze graphs to describe the behavior of functions (e.g., concentration of a solution, phase diagrams, solubility graphs, colligative properties, nuclear decay half-life).

- ✓ **3222.Math.6** Model real-world phenomena using functions and graphs.
- ✓ **3222.Math.7** Apply and interpret algebraic properties in symbolic manipulation (e.g., density, concentration of a solution, chemical equations, effect of volume, temperature or pressure on behavior of a gas, percent composition of elements in a compound, molar mass, number of moles, and molar volume, amount of products or reactants given mole, molarity, volume at STP or mass amounts, heat loss or gain using mass, temperature change and specific heat, and half-life of an isotope).
- ✓ **3222.Math.8** Apply and communicate measurement units, concepts and relationships in algebraic problem-solving situations.
- ✓ **3222.Math.9** Select appropriate units, scales, and measurement tools for problem situations involving proportional reasoning and dimensional analysis.
- ✓ **3222.Math.10** Choose, construct, and analyze appropriate graphical representations for a data set.
- ✓ **3222.Math.11** Identify and solve different types of stoichiometry problems (e.g., volume at STP to mass, moles to mass, molarity).
- ✓ **3222.Math.12** Calculate the amount of product expected in a lab experience and determine percent yield.
- ✓ **3222.Math.13** Convert among the quantities of a substance: mass, number of moles, number of particles, molar volume at STP.

Standard 1 – Structure of Matter

Conceptual Strand 1

Atomic theory is the foundation for understanding the interactions and changes in matter.

Guiding Question 1

How does the structure of matter determine its chemical and physical properties?

Course Level Expectations

- CLE 3222.1.1** Explain and illustrate the arrangement of electrons surrounding an atom.
- CLE 3222.1.2** Relate the arrangement of electrons surrounding an atom with observed periodic trends.
- CLE 3222.1.3** Describe the structure, shape, and characteristics of polyatomic ions, ionic and molecular compounds.

Checks for Understanding (Formative/Summative Assessment)

- ✓ **3222.1.1** Calculate the wavelength, frequency and energy of a photon of electromagnetic radiation.
- ✓ **3222.1.2** Determine the energy level transition of an electron for a particular wavelength of electromagnetic radiation.
- ✓ **3222.1.3** Correlate emission spectra lines of the hydrogen atom to their respective energy-level transitions.
- ✓ **3222.1.4** Describe the arrangement of electrons in an atom using orbital diagrams, electron configuration notation, and Lewis structures.

- ✓3222.1.5 Explain the periodic trends of the main group elements including atomic and ionic radii, ionization energies, and electron affinities.
- ✓3222.1.6 Explain the role of electron shielding and effective nuclear charge in determining the atomic and ionic radii, ionization energy, and electron affinities of an atom or ion.
- ✓3222.1.7 Describe the correlation between the principle quantum number of the valence electrons and the atomic and ionic radii, ionization energy, and electron affinities of an atom or ion.
- ✓3222.1.8 Use Lewis structures to illustrate the structure, shape, and characteristics of polyatomic ions, ionic and molecular compounds.
- ✓3222.1.9 Illustrate the shape of molecular compounds using VSEPR theory.
- ✓3222.1.10 Determine the polarity of a molecular compound by examining its bond dipoles and shape.
- ✓3222.1.11 Apply Lewis structures and formal charge analysis to determine if a compound or polyatomic ion forms resonance structures.
- ✓3222.1.12 Explain the formation of hybridized bond orbitals in molecular compounds using VSEPR and valence bond theory.
- ✓3222.1.13 Illustrate how sigma and pi bonds form between atoms in a molecular compound.
- ✓3222.1.14 Draw the basic functional groups found in organic molecules.
- ✓3222.1.15 Draw the structural formulas of simple organic molecules.

Standard 2 – States of Matter

Conceptual Strand 2

Kinetic-molecular theory and intermolecular forces are the basis for solid, liquid, gas, and solution phenomena.

Guiding Question 2

How does the interaction between ions and molecules determine the physical state and characteristics of matter?

Course Level Expectations

- CLE 3222.1** Explain the kinetic-molecular theory.
- CLE 3222.2** Determine the intermolecular forces that exist between ions and molecules.
- CLE 3222.3** Explain how the physical characteristics of matter are governed by kinetic molecular theory and intermolecular forces.

Checks for Understanding (Formative/Summative Assessment)

- ✓3222.2.1 Correlate the kinetic-molecular theory with the motion of particles within a substance.
- ✓3222.2.2 Explain the effect of heat on temperature in terms of the motion of the particles within the substance.
- ✓3222.2.3 Explain how the motion of gas molecules affects the pressure.
- ✓3222.2.4 Explain the effects of temperature changes on the pressure of a gas.
- ✓3222.2.5 Explain the effects of pressure changes on the volume of a gas.

- ✓3222.2.6 Solve complex combined and ideal gas law problems to quantitatively explain the behavior of gases.
- ✓3222.2.7 Determine the rates of effusion of gas molecules using Graham's Law of Effusion.
- ✓3222.2.8 Describe conditions that cause real gases to deviate from their ideal behavior.
- ✓3222.2.9 Determine the types of intermolecular interactions that occur in a pure substance or between the components of a mixture.
- ✓3222.2.10 Compare the strengths of intermolecular forces between ions, molecules, and ion-molecule mixtures.
- ✓3222.2.11 Correlate the strength of intermolecular force with the viscosity, surface tension and physical state of the substance at a given temperature.
- ✓3222.2.12 Explain the role of intermolecular forces in determining the vapor pressure, volatility and boiling point of a substance.
- ✓3222.2.13 Use a phase diagram to identify the triple-point, critical temperature, and pressure of a substance.
- ✓3222.2.14 Apply a phase diagram to interpret the effects of temperature and pressure on the phase of a substance.
- ✓3222.2.15 Calculate the effect of solute concentration on vapor pressure using Raoult's Law.
- ✓3222.2.16 Calculate the freezing point depression and boiling point elevation of a solution based on appropriate constants, quantities of solute and solvent, and type of solute.
- ✓3222.2.17 Use the freezing or boiling points of the solution, appropriate constants, and the amount solute or solvent to calculate the molar mass of a solute.

Standard 3 – Reactions

Conceptual Strand 3

Chemical reactions can be investigated and described through their stoichiometric, kinetic, equilibrium, and thermodynamic characteristics.

Guiding Question 3

How can the stoichiometric, kinetic, equilibrium, and thermodynamic characteristics of a chemical reaction lead to a further understanding of reaction process?

Course Level Expectations

- CLE 3222.3.1** Use the reactants of a chemical reaction to predict the products.
- CLE 3222.3.2** Fully analyze the quantitative aspects of a chemical reaction in terms of the amounts of products and reactants.
- CLE 3222.3.3** Analyze the kinetics of a chemical reaction.
- CLE 3222.3.4** Describe parameters of chemical equilibria.
- CLE 3222.3.5** Explain the thermodynamics of a chemical reaction.

Checks for Understanding (Formative/Summative Assessment)

- ✓3222.3.1 Apply an activity series to predict products and write net ionic reactions that identify spectator ions in a single-replacement reaction.

- ✓3222.3.2 Use a solubility chart to predict products and write net ionic reactions that identify spectator ions in a double-replacement reaction.
- ✓3222.3.3 Identify the oxidation states of ions in an oxidation-reduction reaction.
- ✓3222.3.4 Balance an oxidation-reduction reaction performed in neutral, acidic, or basic environments.
- ✓3222.3.5 Use reduction potentials to determine the anode and cathode reactions in an electrochemical cell, and calculate its standard reduction potential.
- ✓3222.3.6 Apply reduction potentials to identify oxidizing and reducing agents and determine their relative strengths.
- ✓3222.3.7 Calculate the number of moles, mass, number of ions, atoms, and molecules, volume, and pressure of reactants and products in a chemical reaction based on appropriate constants and quantitative information about reaction components.
- ✓3222.3.8 Calculate the amount of remaining reactants and products in which one of the reactants is limiting.
- ✓3222.3.9 Calculate the rate of a chemical reaction based on elapsed time and amount of remaining reactant or product.
- ✓3222.3.10 Use the rate law and rate of reaction to calculate and interpret the rate constant of a chemical reaction.
- ✓3222.3.11 Calculate and interpret the reaction order based on the rate constant and concentration of reactants or products at various times during the reaction.
- ✓3222.3.12 Draw energy profiles for catalyzed and uncatalyzed chemical reactions in terms of activation energy.
- ✓3222.3.13 Write an equilibrium expression and calculate the equilibrium constant based on the concentration of reactants and products at equilibrium.
- ✓3222.3.14 Interpret the magnitude of the equilibrium constant to determine equilibrium concentrations and direction of a chemical reaction that has yet to reach equilibrium.
- ✓3222.3.15 Apply Le Chatelier's Principle to predict shifts in the direction of a chemical reaction in response to changes in temperature, pressure and concentration of reactants or products.
- ✓3222.3.16 Calculate the percent ionization and pH of a solution given the identity, concentration, and acid/base dissociation constant of an acid or base.
- ✓3222.3.17 Prepare a buffer of a specific pH and calculate the change in pH in response to addition of additional acid or base.
- ✓3222.3.18 Perform a titration of a weak acid or weak base identifying the K_a or K_b and the pH at the equivalence point.
- ✓3222.3.19 Characterize the strength of acids and bases by exploring their chemical structures.
- ✓3222.3.20 Calculate the solubility product constant based on the concentration of soluble ions.
- ✓3222.3.21 Interpret the magnitude of the solubility product constant in terms of the solubility of the substance.
- ✓3222.3.22 Apply thermodynamic data to calculate the change in enthalpy, entropy, and Gibb's free energy of a chemical reaction.
- ✓3222.3.23 Interpret the magnitude of the enthalpy and entropy change of a chemical reaction in terms of heat changes and order of the reaction components.

- ✓ **3222.3.24** Interpret the magnitude of free energy change in terms of spontaneity of the chemical reaction.
- ✓ **3222.3.25** Relate the magnitude of the free energy change to the equilibrium condition and reduction potential of a chemical reaction.

Tennessee Science Curriculum Framework

Environmental Science

Course Description

Environmental Science is a laboratory course that enables students to develop an understanding of the natural and human-made environment and the environmental problems that the world faces. Students explore environmental science concepts through an inquiry approach.

Environmental Science students investigate:

- Inquiry
- Technology and Engineering
- Earth Systems
- The Living World
- Human Population
- Water and Land Resources
- Energy Resources and Consumption
- Pollution and Waste Production
- Global Change and Civic Responsibility

Embedded Inquiry

Conceptual Strand

Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21st century.

Guiding Question

What tools, skills, knowledge, and dispositions are needed to conduct scientific inquiry?

Course Level Expectations

CLE 3260.Inq.1 Recognize that science is a progressive endeavor that reevaluates and extends what is already accepted.

CLE 3260.Inq.2 Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.

CLE 3260.Inq.3 Use appropriate tools and technology to collect precise and accurate data.

CLE 3260.Inq.4 Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.

CLE 3260.Inq.5 Compare experimental evidence and conclusions with those drawn by others about the same testable question.

CLE 3260.Inq.6 Communicate and defend scientific findings.

Checks for Understanding (Formative/Summative Assessment)

- ✓3260.Inq.1 Develop a testable question for a scientific investigation.
- ✓3260.Inq.2 Develop an experimental design for testing a hypothesis.
- ✓3260.Inq.3 Select appropriate independent, dependent, or controlled variables for an experiment.
- ✓3260.Inq.4 Perform an experiment to test a prediction.
- ✓3260.Inq.5 Gather, organize, and transform data from an experiment.
- ✓3260.Inq.6 Analyze and interpret the results of an experiment.
- ✓3260.Inq.7 Use knowledge and data-interpretation skills to support a conclusion.
- ✓3260.Inq.8 State a conclusion in terms of the relationship between two or more variables.
- ✓3260.Inq.9 Compare the results of an experiment with what is already known about the topic under investigation.
- ✓3260.Inq.10 Suggest alternative explanations for the same observations.
- ✓3260.Inq.11 Analyze experimental results and identify possible sources of bias or experimental error.
- ✓3260.Inq.12 Formulate and revise scientific explanations and models using logic and evidence.
- ✓3260.Inq.13 Develop a logical argument about cause-and-effect relationships in an experiment.

Embedded Technology and Engineering

Conceptual Strand

Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.

Guiding Question

How do science concepts, engineering skills, and applications of technology improve the quality of life?

Course Level Expectations

- CLE 3260.T/E.1** Explore the impact of technology on social, political, and economic systems.
- CLE 3260.T/E.2** Differentiate among elements of the engineering design cycle: design constraints, model building, testing, evaluating, modifying, and retesting.
- CLE 3260.T/E.3** Explain the relationship between the properties of a material and the use of the material in the application of a technology.
- CLE 3260.T/E.4** Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems.

Checks for Understanding (Formative/Summative Assessment)

- ✓3260. T/E.1 Select appropriate tools to conduct a scientific inquiry.
- ✓3260. T/E.2 Apply the engineering design process to construct a prototype that meets developmentally appropriate specifications.

- ✓3260. T/E.3 Explore how the unintended consequences of new technologies can impact human and non-human communities.
- ✓3260. T/E.4 Present research on current bioengineering technologies that advance health and contribute to improvements in our daily lives.
- ✓3260. T/E.5 Design a series of multi-view drawings that can be used by other students to construct an adaptive design and test its effectiveness.

Standard 1 – Earth Systems

Conceptual Strand 1

Abiotic factors exert a profound influence on the global ecosystem.

Guiding Question 1

How do abiotic factors sustain life on earth?

Course Level Expectations

- CLE 3260.1.1** Explain how earth’s position in the solar system creates global climate patterns.
- CLE 3260.1.2** Use the theory of plate tectonics to explain the occurrence of earthquakes, volcanoes, and tsunamis.
- CLE 3260.1.3** Explain the rock cycle and its association with soil formation.
- CLE 3260.1.4** Relate the atmosphere, hydrosphere and lithosphere to the biosphere.

Checks for Understanding (Formative/Summative Assessment)

- ✓3260.1.1 Use a globe to explain the global circulation of the atmosphere integrating the uneven heating of Earth’s surface and Earth’s rotation.
- ✓3260.1.2 Sketch and label a diagram of the layers of the atmosphere indicating distance above Earth’s surface, temperature changes and other significant characteristics for each layer.
- ✓3260.1.3 Use a one gallon container of water as a scale model to explain what percentage of water on Earth occurs as oceans, glaciers, freshwater and groundwater.
- ✓3260.1.4 Compare heat transfer in the atmosphere and the oceans.
- ✓3260.1.5 Describe how gases in the atmosphere affect climate.
- ✓3260.1.6 Differentiate between divergent, convergent and transform plate boundaries.
- ✓3260.1.7 Create a concept map depicting the rock cycle.
- ✓3260.1.8 Relate erosion (weathering and transportation) to soil formation.
- ✓3260.1.9 Differentiate between the hydrosphere, lithosphere and atmosphere.

Standard 2 – The Living World

Conceptual Strand 2

The global ecosystem involves interactions between biotic and abiotic factors.

Guiding Question 2

How do living things interact with each other and the abiotic components of the environment?

Course Level Expectations

- CLE 3260.2.1** Employ the first and second laws of thermodynamics to explain energy flow within ecosystems.
- CLE 3260.2.2** Discuss the roles of biodiversity and coevolution in ecosystems.
- CLE 3260.2.3** Using temperature, latitude and altitude, infer the types of animal and plant life found in each of earth's major biomes.
- CLE 3260.2.4** Distinguish between primary and secondary biological succession using common plants and animals.
- CLE 3260.2.5** Explain biogeochemical cycling in ecosystems.

Checks for Understanding (Formative/Summative Assessment)

- ✓**3260.2.1** Trace energy flow from the sun through living things.
- ✓**3260.2.2** Diagram an energy/food pyramid that illustrates the 'Rule of 10'.
- ✓**3260.2.3** Create a food web characteristic of a Tennessee ecoregion composed of at least four trophic levels. Extract two different, four trophic level food chains.
- ✓**3260.2.4** Describe how species biodiversity relates to ecosystem stability.
- ✓**3260.2.5** Describe plant and animal adaptations found in each of earth's major biomes.
- ✓**3260.2.6** Identify the locations of earth's major biomes using a globe or map.
- ✓**3260.2.7** Develop a visual display to compare and contrast primary and secondary biological succession in one of earth's major biomes or aquatic habitats.
- ✓**3260.2.8** Explain how human activities such as lawn mowing, gardening, farming, logging, planting trees, mining, and urban development advance, halt, or slow succession.
- ✓**3260.2.9** Draw and explain diagrams illustrating each of the following biogeochemical cycles: water, carbon, nitrogen and phosphorus.

Standard 3 – Human Population

Conceptual Strand 3

Worldwide, human population is growing exponentially.

Guiding Question 3

What factors affect human population growth?

Course Level Expectations

- CLE 3260.3.1** Demonstrate how human population growth over time has been affected by improved food production, healthcare, sanitation and industrial advances.
- CLE 3260.3.2** Research demographics and economic status of different countries to infer ecological and economic consequences of human population growth.
- CLE 3260.3.3** Explain how social and economic factors affect the fertility rate and life expectancy of the human population.

Checks for Understanding (Formative/Summative Assessment)

- ✓3260.3.1 Interpret and create graphs depicting human populations.
- ✓3260.3.2 Compare and contrast population growth rates and demographics for countries at various stages of economic development.
- ✓3260.3.3 Analyze age structure diagrams to predict population growth rates.
- ✓3260.3.4 Describe how the U.S. population experienced demographic transition.
- ✓3260.3.5 Use the concept of the ecological footprint to predict the ecological consequences of human population growth.
- ✓3260.3.6 Discuss pros and cons of methods used to manage a country's population growth.

Standard 4 – Water and Land Resources

Conceptual Strand 4

Humans use natural resources in a variety of ways.

Guiding Question 4

How can natural resources be sustainably managed for the benefit of all living things?

Course Level Expectations

- CLE 3260.4.1** Examine common resource use practices in agriculture, forestry, urban/suburban development, mining, and fishing.
- CLE 3260.4.2** Explore best management practices related to water and soil resources.
- CLE 3260.4.3** Compare and contrast preservation and conservation.
- CLE 3260.4.4** Evaluate the impact of human activities on natural resources.

Checks for Understanding (Formative/Summative Assessment)

- ✓3260.4.1 Differentiate between renewable and nonrenewable resources.
- ✓3260.4.2 Summarize how environmental problems (e.g., erosion, desertification, acid deposition, simplified ecosystems, and soil salinization) are associated with farming practices and soil conservation practices.
- ✓3260.4.3 Investigate the impact of the green revolution on world food production and on the environment.
- ✓3260.4.4 Investigate the pros and cons of producing crops through genetic engineering.
- ✓3260.4.5 Summarize the ecological services and economic benefits provided by forests.
- ✓3260.4.6 Summarize the environmental impact of extracting, processing, and using mineral resources.
- ✓3260.4.7 Conduct a controlled experiment to determine effects of soil salinization on seed germination.
- ✓3260.4.8 Use an environmentally significant case study (e.g., oil exploration in the Alaskan Wildlife Refuge) to explain the difference between preservation and conservation.
- ✓3260.4.9 Summarize the roles of various public and private organizations (e.g., Nature Conservancy, Sierra Club, National Wildlife Federation, World Wildlife Fund, U.S. Forest Service, U.S. Fish and Wildlife, Bureau of Land Management, Department of Interior, Tennessee Wildlife Resource Agency, Tennessee

Department of Environment and Conservation) involved in natural resource protection and use.

- ✓**3260.4.10** Research a Tennessee city, such as Chattanooga. Incorporate green design features into a plan for sustainable development in your community.
- ✓**3260.4.11** Research and summarize U.S. environmental laws related to natural resources (e.g., Resource Conservation and Recovery Act, Surface Mining Control and Reclamation Act, Food Quality Protection Act, Endangered Species Act, Soil Conservation Act, and National Park Service Act).

Standard 5 – Energy Resources and Consumption

Conceptual Strand 5

Humans use both renewable and nonrenewable sources of energy.

Guiding Question 5

What are the environmental consequences of energy use?

Course Level Expectations

- CLE 3260.5.1** Compare and contrast various energy resources.
- CLE 3260.5.2** Analyze the past and present use of energy resources.
- CLE 3260.5.3** Predict future trends in energy resource use.

Checks for Understanding (Formative/Summative Assessment)

- ✓**3260.5.1** Construct visual displays to illustrate the source, uses, advantages, disadvantages, availability, and cost of energy resources (i.e. coal, petroleum, nuclear, solar, hydro, wind, geothermal, biofuels, Hydrogen, tidal, “OTEC”).
- ✓**3260.5.2** Explain the concept of full cost pricing as it relates to electricity production.
- ✓**3260.5.3** Summarize renewable and nonrenewable energy use and consumption through time.
- ✓**3260.5.4** Compare the energy consumption of common appliances/electronic devices.
- ✓**3260.5.5** Describe energy saving alternatives to common appliances and electronic devices and explore energy saving alternatives.
- ✓**3260.5.6** Calculate personal carbon footprint and formulate plans for personal and commercial energy conservation.
- ✓**3260.5.7** Research technological advances in energy resources.
- ✓**3260.5.8** Research technological advances in energy conservation.

Standard 6 – Waste Production and Pollution

Conceptual Strand 6

Many human activities result in pollution.

Guiding Question 6

How can we mimic nature to provide goods and services for the growing human population in ways that do not pollute the environment?

Course Level Expectations

- CLE 3260.6.1** Investigate the causes, environmental effects, and methods for controlling/preventing land, air and water pollution.
- CLE 3260.6.2** Apply case studies to relate land, air, and water pollution to human health issues.
- CLE 3260.6.3** Explore methods used for remediation of land, air and water pollution.
- CLE 3260.6.4** Research local and national environmental legislation related to protecting land, air and water resources.
- CLE 3260.6.5** Research local and state methods used for solid waste reduction, recycling and disposal; compare them to methods used in other developed countries.

Checks for Understanding (Formative/Summative Assessment)

- ✓**3260.6.1** Differentiate between point and non-point sources of pollution as they apply to air and water.
- ✓**3260.6.2** Conduct a watershed analysis of a local stream. Test for chemical and biological (infectious) pollutants include a survey of macro invertebrates.
- ✓**3260.6.3** Investigate a state or local environmental issue involving pollution of land, air or water.
- ✓**3260.6.4** Explore case studies of human health problems related to pollutants.
- ✓**3260.6.5** Research major U.S. Environmental Legislation such as National Environmental Policy Act of 1969 (NEPA), The Clean Air Act, The Clean Water Act, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund), Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), The Oil Pollution Act of 1990 (OPA), The Pollution Prevention Act (PPA), The Resource Conservation and Recovery Act (RCRA), The Safe Drinking Water Act (SWDA), The Toxic Substances Control Act (TSCA).
- ✓**3260.6.6** Compare and contrast industrial agricultural practices emphasizing use of petroleum based pesticides and fertilizers with organic methods of food production that utilize integrated pest management and organic composting.
- ✓**3260.6.7** Conduct a survey about waste management/recycling habits and opportunities in your community. Report findings in an article written for a local newspaper, a pod-cast or on a local talk radio show.
- ✓**3260.6.8** Investigate what watershed your school is located in and how wastewater, municipal solid and hazardous wastes are handled.

Standard 7 – Global Change and Civic Responsibility

Conceptual Strand 7

Human interaction with the local environment has global consequences.

Guiding Question 7

How do the decisions of one generation create opportunities and impose limitations for future generations?

Course Level Expectations

- CLE 3260.7.1** Explain how consumer choices in Tennessee impact jobs, resources, pollution and waste here and around the world.
- CLE 3260.7.2** Compare and contrast methods used by various governments to protect biodiversity.
- CLE 3260.7.3** Explain how human activity is related to ozone depletion and climate change.
- CLE 3260.7.4** Summarize the scientific explanation for average global temperature increase.

Checks for Understanding (Formative/Summative Assessment)

- ✓**3260.7.1** Interview a senior citizen about past use and disposal of resources and compare with common practices today.
- ✓**3260.7.2** Compare and contrast industrial agriculture and sustainable agriculture.
- ✓**3260.7.3** Identify how environmental protection can be carried out on a local level and explain choices that can be made to lessen the impact on the environment.
- ✓**3260.7.4** Choose three endangered species and predict how their removal would affect the ecosystems in which they live.
- ✓**3260.7.5** Research the effectiveness of the U.S. Endangered Species Act.
- ✓**3260.7.6** Research major international environmental issues and how they are addressed by international agreements (Kyoto, Montreal, CITES, etc.).
- ✓**3260.7.7** Compare and contrast stratospheric and tropospheric ozone.
- ✓**3260.7.8** Define chlorofluorocarbons and explain how they break down ozone molecules.
- ✓**3260.7.9** Explain the trend in atmospheric CO₂ levels indicated by ice core data and CO₂ measurements recorded at Mauna Loa since 1958.
- ✓**3260.7.10** Predict the consequences of a warmer earth.

Tennessee Science Curriculum Framework

Earth Science

Course Description

Earth Science is a laboratory course that explores the origins and the connections among the physical, chemical, and biological processes of the earth system. Students experience the content through *inquiry-based laboratory and field investigations*. Course topics include: matter, energy, crystal dynamics, cosmic evolution, and structure, cycles, geochemical processes, and the expanded time scales necessary to understand events in the earth system. Earth Science provides the knowledge, skills, and habits of mind needed for problem-solving and ethical decision-making about scientific and technological concerns.

Earth Science students investigate:

- Inquiry
- Technology and Engineering
- The Universe
- Energy in the Earth System
- Cycles in the Earth System
- Geologic History

Embedded Inquiry

Conceptual Strand

Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21st century.

Guiding Question

What tools, skills, and knowledge are needed to conduct scientific inquiry?

Course Level Expectations

CLE 3204.Inq.1 Recognize that science is a progressive endeavor that reevaluates and extends what is already accepted.

CLE 3204.Inq.2 Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.

CLE 3204.Inq.3 Use appropriate tools and technology to collect precise and accurate data.

CLE 3204.Inq.4 Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.

CLE 3204.Inq.5 Compare experimental evidence and conclusions with those drawn by others about the same testable question.

CLE 3204.Inq.6 Communicate and defend scientific findings.

Checks for Understanding (Formative/Summative Assessment)

- ✓**3204.Inq.1** Trace the historical development of a scientific principle or theory, such as plate tectonics, evolution of the cosmos, and global change.
- ✓**3204.Inq.2** Conduct scientific investigations that include testable questions, verifiable hypotheses, and appropriate variables to explore new phenomena or verify the experimental results of others.
- ✓**3204.Inq.3** Select appropriate tools and technology to collect precise and accurate quantitative and qualitative data.
- ✓**3204.Inq.4** Determine if data supports or contradicts a hypothesis or conclusion.
- ✓**3204.Inq.5** Compare or combine experimental evidence from two or more investigations.
- ✓**3204.Inq.6** Recognize, analyze, and evaluate alternative explanations for the same set of observations.
- ✓**3204.Inq.7** Evaluate the accuracy and precision of data.
- ✓**3204.Inq.8** Analyze experimental results and identify possible sources of bias or experimental error.
- ✓**3204.Inq.9** Formulate and revise scientific explanations and models using logic and evidence.

Embedded Technology and Engineering

Conceptual Strand

Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.

Guiding Question

How do science concepts, engineering skills, and applications of technology improve the quality of life?

Course Level Expectations

- CLE 3204.T/E.1** Explore the impact of technology on social, political, and economic systems.
- CLE 3204.T/E.2** Differentiate among elements of the engineering design cycle: design constraints, model building, testing, evaluating, modifying, and retesting.
- CLE 3204.T/E.3** Explain the relationship between the properties of a material and the use of the material in the application of a technology.
- CLE 3204.T/E.4** Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems.

Checks for Understanding (Formative/Summative Assessment)

- ✓**3204.T/E.1** Distinguish among tools and procedures best suited to conduct a specified scientific inquiry.
- ✓**3204.T/E.2** Apply the engineering design process to construct a prototype that meets developmentally appropriate specifications.
- ✓**3204.T/E.3** Evaluate a protocol to determine the degree to which an engineering design process was successfully applied.

- ✓3204.T/E.4 Explore how the unintended consequences of new technologies can impact human and non-human communities.
- ✓3204.T/E.5 Evaluate the overall benefit to cost ratio of a new technology.
- ✓3204.T/E.6 Present research on current bioengineering technologies that advance health and contribute to improvements in our daily lives.
- ✓3204.T/E.7 Design a series of multi-view drawings that can be used by other students to construct an adaptive design and test its effectiveness.

Standard 1 – The Universe

Conceptual Strand 1

The cosmos is vast and explored well enough to know its basic structure and operational principles.

Guiding Question 1

What big ideas guide human understanding about the origin and structure of the universe, Earth's place in the cosmos, and observable motions and patterns in the sky?

Course Level Expectations

- CLE 3204.1.1** Explore theories for the origin and evolution of the universe.
- CLE 3204.1.2** Examine the components of the solar system.
- CLE 3204.1.3** Explore the sun, earth, and moon relationships and their gravitational effects.
- CLE 3204.1.4** Investigate the history of space exploration.

Checks for Understanding (Formative/Summative Assessment)

- ✓3204.1.1 Identify the components of the universe: black holes, galaxies, nebulae, solar systems, stars, planets, meteors, comets, and asteroids.
- ✓3204.1.2 Compare explanations for the origin of the universe: Big Bang, nucleosynthesis, galaxy, and star formation.
- ✓3204.1.3 Construct a solar system model that illustrates ratios and proportions of distance and size of planets.
- ✓3204.1.4 Explain the evolution of a star through stages of its development.
- ✓3204.1.5 Classify galaxies according to shape.
- ✓3204.1.6 Explore the role of astronomical events in the earth's history: asteroid/meteor impacts, solar flares, and comets.
- ✓3204.1.7 Compare and contrast the earth with other planets in the solar system.
- ✓3204.1.8 Investigate the seasonal relationships between the length of the day and the inclination and relative positions of the sun and earth.
- ✓3204.1.9 Describe the position of the sun, earth, and moon during eclipses and different lunar phases.
- ✓3204.1.10 Predict tidal conditions based upon the position of the earth, moon, and sun.
- ✓3204.1.11 Describe the relationship between the mass of an object and the its gravitational force.
- ✓3204.1.12 Construct a historical timeline that depicts man's changing perceptions and understanding of astronomy.

- ✓3204.1.13 Understand how telescopes and spectroscopy manipulate light to reveal information about the universe.
- ✓3204.1.14 Investigate the history of space exploration.
- ✓3204.1.15 Research Tennessee's contribution to earth and space science.

Standard 2 - Energy in the Earth System

Conceptual Strand

Energy cycles drive the earth system.

Guiding Question

What are the scientific explanations for how energy cycles through the earth system?

Course Level Expectations

- CLE 3204.2.1 Investigate the principal sources of energy.
- CLE 3204.2.2 Explore pathways of energy transfer.
- CLE 3204.2.3 Evaluate alternative energy sources.

Checks for Understanding (Formative/Summative Assessment)

- ✓3204.2.1 Differentiate among the various forms of energy.
- ✓3204.2.2 Illustrate three types of energy transfer: radiation, conduction, and convection.
- ✓3204.2.3 Describe different types of energy resources: fossil fuels, solar, geothermal, nuclear, wind, and hydroelectric.
- ✓3204.2.4 Distinguish between renewable and nonrenewable resources in terms of resource conservation.
- ✓3204.2.5 Investigate how the sun provides the major source of earth's surface energy.
- ✓3204.2.6 Explore three primary sources of internal energy: gravitational energy from the earth's original formation, friction, and radioactive decay.
- ✓3204.2.7 Diagram and evaluate pathways of energy transfer to demonstrate the law of conservation of energy.
- ✓3204.2.8 Describe the energy transfer associated with different geologic events: mantle convection, rock cycle, wind, and ocean currents.
- ✓3204.2.9 Describe the human impact of large scale energy transfer events: hurricanes, photosynthesis, earthquakes, volcanoes, and tsunamis.
- ✓3204.2.10 Compare and contrast alternative energy sources and their environmental impact.
- ✓3204.2.11 Compare energy sources and heat transfer over geologic time to current patterns of global change.

Standard 3 - Cycles in the Earth System

Conceptual Strand

The earth system consists of interrelated subcycles that act over extended periods of geologic time.

Guiding Question

What are the subcycles of the earth system and how do they interact?

Course Level Expectations

- CLE 3204.3.1 Explain the components of the tectonic cycle.
- CLE 3204.3.2 Investigate the rock cycle.
- CLE 3204.3.3 Analyze the hydrologic cycle.
- CLE 3204.3.4 Interpret data related to the atmospheric cycle.
- CLE 3204.3.5 Differentiate among the geochemical cycles.
- CLE 3204.3.6 Evaluate the impact of living organisms on earth system cycles.
- CLE 3204.3.7 Investigate how maps can be used to interpret changes in the earth system.
- CLE 3204.3.8 Relate earth system cycles to past and current patterns of global change.

Checks for Understanding (Formative/Summative Assessment)

- ✓3204.3.1 Use models to explain the theory of plate tectonics.
- ✓3204.3.2 Apply mantle convection currents to distinguish between divergent and convergent plate boundaries.
- ✓3204.3.3 Explain and map the relationship between plate tectonics and mountain building, volcanoes, and earthquakes.
- ✓3204.3.4 Distinguish between minerals and rocks.
- ✓3204.3.5 Identify minerals according to their physical properties.
- ✓3204.3.6 Distinguish among sedimentary, igneous, and metamorphic rocks.
- ✓3204.3.7 Interpret a diagram of the rock cycle.
- ✓3204.3.8 Explain a model of the hydrologic cycle.
- ✓3204.3.9 Distinguish between mechanical and chemical weathering.
- ✓3204.3.10 Describe the impact of water on the evolution of landforms.
- ✓3204.3.11 Collect and interpret basic weather data from meteorological instruments: thermometer, rain gauge, and barometer.
- ✓3204.3.12 Analyze weather map data to make simple predictions.
- ✓3204.3.13 Explain the oxygen/carbon dioxide, nitrogen, and carbon biogeochemical cycles.
- ✓3204.3.14 Recognize the connection between geologic processes such as floods, earthquakes, volcanoes, acid rain, global warming and human activities.
- ✓3204.3.15 Construct a geological cycle for a physiographic region or geologic time period in Tennessee.
- ✓3204.3.16 Interpret topographic maps.
- ✓3204.3.17 Relate current global patterns such as sea level change and geographic climate shifts to events that occurred during the earth's distant past.

Standard 4 - Geologic History

Conceptual Strand

The earth has changed over a long period and global change is a continuation of this evolutionary process.

Guiding Question

What is the scientific evidence for the evolution of earth and life on earth?

Course Level Expectations

- CLE 3204.4.1 Interpret the nature of geologic time.

CLE 3204.4.2 Investigate the evolution of the earth.

CLE 3204.4.3 Interpret the fossil record for evidence of biological evolution.

CLE 3204.4.4 Demonstrate the impact of environmental change on the origin and extinction of plant and animal species.

Checks for Understanding (Formative/Summative Assessment)

✓**3204.4.1** Explain the law of uniformitarianism.

✓**3204.4.2** Differentiate between absolute and relative time.

✓**3204.4.3** Compare and contrast how relative and absolute dating techniques are used to interpret the advance of geologic history.

✓**3204.4.4** Construct a geologic timetable for the evolution of earth and the history of life.

✓**3204.4.5** Interpret evidence for plate tectonics such as the fossil record, mountain range formation, rock strata, paleomagnetism, paleoclimates, and configuration of the continents.

✓**3204.4.6** Recognize that fossils contained in sedimentary rock provide evidence of past life forms, changes in life forms, and environmental change.

✓**3204.4.7** Determine the relative age of fossils in sedimentary rock.

✓**3204.4.8** Interpret the sequence of rock strata using superposition, cross-cutting relationships, inclusions, the fossil record, and absolute dating techniques.

✓**3204.4.9** Predict how an environmental change might influence the development of new species or cause the extinction of an existing species.

Tennessee Science Curriculum Framework

Geology

Course Description

Geology is a laboratory course that explores the origins and the connections among the physical, chemical, and biological processes of the earth system. Students explore the physical aspects of earth processes and cycles through *inquiry-based field and laboratory investigations*.

Understanding the importance of these processes and how they influence humankind enables students to make sound decisions about their community and the earth's global environment.

Geology students investigate:

- Inquiry
- Technology and Engineering
- Maps
- Matter and Minerals
- The Rock Cycle
- Geologic History
- Plate Tectonics
- Landforms

Embedded Inquiry

Conceptual Strand

Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21st century.

Guiding Question

What tools, skills, knowledge, and dispositions are needed to conduct scientific inquiry?

Course Level Expectations

CLE 3205.Inq.1 Recognize that science is a progressive endeavor that reevaluates and extends what is already accepted.

CLE 3205.Inq.2 Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.

CLE 3205.Inq.3 Use appropriate tools and technology to collect precise and accurate data.

CLE 3205.Inq.4 Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.

CLE 3205.Inq.5 Compare experimental evidence and conclusions with those drawn by others about the same testable question.

CLE 3205.Inq.6 Communicate and defend scientific findings.

Checks for Understanding (Formative/Summative Assessment)

- ✓**3205.Inq.1** Trace the historical development of a scientific principle or theory, such as plate tectonics, evolution of landforms, and global climate change.
- ✓**3205.Inq.2** Conduct scientific investigations that include testable questions, verifiable hypotheses, and appropriate variables to explore new phenomena or verify the experimental results of others.
- ✓**3205.Inq.3** Select appropriate tools and technology to collect precise and accurate quantitative and qualitative data.
- ✓**3205.Inq.4** Determine if data supports or contradicts a hypothesis or conclusion.
- ✓**3205.Inq.5** Compare or combine experimental evidence from two or more investigations.
- ✓**3205.Inq.6** Recognize, analyze, and evaluate alternative explanations for the same set of observations.
- ✓**3205.Inq.7** Evaluate the accuracy and precision of data.
- ✓**3205.Inq.8** Analyze experimental results and identify possible sources of bias or experimental error.
- ✓**3205.Inq.9** Formulate and revise scientific explanations and models using logic and evidence.

Embedded Technology and Engineering

Conceptual Strand

Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.

Guiding Question

How do science concepts, engineering skills, and applications of technology improve the quality of life?

Course Level Expectations

- CLE 3205.T/E.1** Explore the impact of technology on social, political, and economic systems.
- CLE 3205.T/E.2** Differentiate among elements of the engineering design cycle: design constraints, model building, testing, evaluating, modifying, and retesting.
- CLE 3205.T/E.3** Explain the relationship between the properties of a material and the use of the material in the application of a technology.
- CLE 3205.T/E.4** Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems.

Checks for Understanding (Formative/Summative Assessment)

- ✓**3205.T/E.1** Distinguish among tools and procedures best suited to conduct a specified scientific inquiry.
- ✓**3205.T/E.2** Apply the engineering design process to construct a prototype that meets developmentally appropriate specifications.
- ✓**3205.T/E.3** Evaluate a protocol to determine the degree to which an engineering design process was successfully applied.

- ✓3205.T/E.4 Explore how the unintended consequences of new technologies can impact human and non-human communities.
- ✓3205.T/E.5 Evaluate the overall benefit to cost ratio of a new technology.
- ✓3205.T/E.6 Present research on current bioengineering technologies that advance health and contribute to improvements in our daily lives.
- ✓3205.T/E.7 Design a series of multi-view drawings that can be used by other students to construct an adaptive design and test its effectiveness.

Standard 1 - Maps

Conceptual Strand

Maps represent earth's landforms and provide tools for studying geologic processes.

Guiding Question

What geologic features are represented on maps and how can maps provide clues that explain geologic processes?

Course Level Expectations

CLE 3205.1.1 Read and interpret topographic and geologic maps.

CLE 3205.1.2 Use geologic maps to investigate rock types, time periods, and faults and folds.

CLE 3205.1.3 Investigate technologies used to create maps.

CLE 3205.1.4 Apply maps for planning purposes and to investigate land-use problems.

Checks for Understanding (Formative/Summative Assessment)

✓3205.1.1 Identify basic map symbols and legends.

✓3205.1.2 Differentiate between longitude and latitude.

✓3205.1.3 Determine the latitude and longitude of specific map points.

✓3205.1.4 Investigate the concept of map scale.

✓3205.1.5 Determine scaled map distances.

✓3205.1.6 Explain the concept of elevation.

✓3205.1.7 Determine the elevations of specific points on a topographic map.

✓3205.1.8 Construct a 3-D representation of a topographical map that illustrates contour lines.

✓3205.1.9 Construct an elevation profile from topographic map data

✓3205.1.10. Identify landforms and determine stream flow direction using a topographic map.

✓3205.1.11 Use field data to create a topographic map of a landform

✓3205.1.12 Interpret basic rock types, time periods, and faults from geologic maps.

✓3205.1.13 Determine compass readings at selected sites.

✓3205.1.14 Investigate methods of remote sensing used to measure and monitor the earth's crust.

✓3205.1.15 Use a GPS unit to identify latitude, longitude, and elevation of a location.

Standard 2 - Matter and Minerals

Conceptual Strand

Minerals are naturally occurring substances formed through geological processes that have characteristic physical and chemical properties.

Guiding Question

How do minerals form and what are their unique characteristics?

Course Level Expectations

- CLE 3205.2.1 Describe how atoms serve as building blocks for all matter.
- CLE 3205.2.2 Apply the periodic table to determine the properties of an element.
- CLE 3205.2.3 Describe the geologic processes that result in mineral formation.
- CLE 3205.2.4 Distinguish between the physical and chemical properties of minerals.
- CLE 3205.2.5 Investigate the structure and geometry of crystals.

Checks for Understanding (Formative/Summative Assessment)

- ✓3205.2.1 Create a model of an atom based on information found in the periodic table.
- ✓3205.2.2 Classify a substance as an element or a compound.
- ✓3205.2.3 Interpret the periodic table to identify groups of elements as reactive or non-reactive metals, nonmetals, or gases.
- ✓3205.2.4 Explore the physical and chemical properties of minerals.
- ✓3205.2.5 Identify mineral samples using simple physical property tests and a mineral identification table.
- ✓3205.2.6 Recognize that water is a major solvent that releases elements and minerals from earth materials.
- ✓3205.2.7 Describe the crystal structure of minerals in terms of atomic size, method of bonding, and the environment.
- ✓3205.2.8 Construct models of the six major crystal systems.
- ✓3205.2.9 Classify minerals such as silicates, native elements, carbonate, and sulfates according to their chemical formulas.
- ✓3205.2.10 Create a presentation for a mineral that includes its physical properties, an illustration, mining technique, occurrence, and use.
- ✓3205.2.11 Explore gems and their importance to man.
- ✓3205.2.12 Create a brochure on the mineral resources of Tennessee.

Standard 3 - The Rock Cycle

Conceptual Strand

The rock cycle explains how different rock types are related to each other and how earth processes transform rocks from one type to another over geologic time.

Guiding Question

How does the rock cycle explain the origin of different rock types?

Course Level Expectations

- CLE 3205.3.1 Identify and differentiate among the three rock groups.

- CLE 3205.3.2** Describe the processes responsible for forming the three rock groups.
CLE 3205.3.3 Examine the characteristics of each rock group.
CLE 3205.3.4 Explain the rock cycle.

Checks for Understanding (Formative/Summative Assessment)

- ✓**3205.3.1** Distinguish among sedimentary, igneous, and metamorphic rocks.
- ✓**3205.3.2** Diagram the rock cycle including the processes involved in the formation of each rock group.
- ✓**3205.3.3** Recognize that rocks are composed of various combinations of minerals.
- ✓**3205.3.4** Distinguish between intrusive (plutonic) and extrusive (volcanic) igneous rocks.
- ✓**3205.3.5** Differentiate among plutonic bodies such as sills, dikes, batholiths, and laccoliths.
- ✓**3205.3.6** Identify the properties of igneous rocks such as granite, rhyolite, basalt, gabbro, obsidian, and pumice.
- ✓**3205.3.7** Understand sedimentary processes.
- ✓**3205.3.8** Distinguish between clastic, chemical, and biogenic textures and processes forming each.
- ✓**3205.3.9** Identify sedimentary rock features such as stratification, fossils, graded bedding, ripple marks, and mudcracks.
- ✓**3205.3.10** Identify the properties of sedimentary rocks such as sandstone, shale, limestone, coquina, coal, and conglomerate.
- ✓**3205.3.11** Differentiate between foliated and non-foliated metamorphic rocks.
- ✓**3205.3.12** Compare and contrast regional and contact metamorphism.
- ✓**3205.3.13** Identify the properties of metamorphic rocks such as gneiss, marble, schist, slate, and quartzite.
- ✓**3205.3.14** Interpret Bowen's reaction series.
- ✓**3205.3.15** Describe gradational metamorphism based on index minerals and metamorphic rock types.

Standard 4 - Geologic History

Conceptual Strand

The earth has changed over a long period and global change is a continuation of that evolutionary process.

Guiding Question

What is the scientific evidence for the evolution of earth and life on earth?

Course Level Expectations

- CLE 3205.4.1** Interpret the nature of geologic time.
- CLE 3205.4.2** Investigate the evolution of earth.
- CLE 3205.4.3** Investigate the history of life.
- CLE 3205.4.4** Interpret the fossil record for evidence of biological evolution.
- CLE 3205.4.5** Demonstrate the impact of environmental change on the origin and extinction of plant and animal species.

CLE 3205.4.6 Investigate the long-term aspects of global change and explain how these events have influenced current global patterns.

Checks for Understanding (Formative/Summative Assessment)

- ✓**3205.4.1** Describe how scientists estimate the age of the earth.
- ✓**3205.4.2** Compare and contrast how relative and absolute dating techniques are used to interpret geologic history.
- ✓**3205.4.3** Construct a geologic timetable that illustrates the evolution of earth and the history of life.
- ✓**3205.4.4** Explain the law of uniformitarianism.
- ✓**3205.4.5** Recognize that fossils are found in sedimentary rock.
- ✓**3205.4.6** Compare and contrast fossil forms of life with modern organisms.
- ✓**3205.4.7** Recognize that fossils provide evidence of past life forms, changes in life forms, and past environmental conditions.
- ✓**3205.4.8** Examine the fossil record to describe the environmental adaptations in a group of organisms.
- ✓**3205.4.9** Describe the evidence for plate tectonics such as fossil record, mountain ranges, rock strata, paleomagnetism, paleoclimates, and the configuration of continents.
- ✓**3205.4.10** Determine the relative age of fossils in sedimentary rock.
- ✓**3205.4.11** Interpret the sequence of rock strata using superposition, cross-cutting relationships, inclusions, the fossil record, and absolute data techniques.
- ✓**3205.4.12** Predict how an environmental change will affect the development of new species or the extinction of an existing species.
- ✓**3205.4.13** Make a timeline of global change through geologic time such as sea level change, climate change, paleogeographic change, and biotas.

Standard 5 - Plate Tectonics

Conceptual Strand

Plate tectonics is the grand unifying theory of geology.

Guiding Question

How does the theory of plate tectonics connect all geologic processes and explain major geologic phenomena?

Course Level Expectations

- CLE 3205.5.1** Describe the major evidence to explain the theory of plate tectonics.
- CLE 3205.5.2** Recognize different types of plate boundaries.
- CLE 3205.5.3** Explain how convection currents provide the driving mechanism for plate movement.
- CLE 3205.5.4** Describe processes associated with volcanoes, earthquakes, and mountain building.

Checks for Understanding (Formative/Summative Assessment)

- ✓**3205.5.1** Identify plate boundaries on a diagram.
- ✓**3205.5.2** Match continent boundary shapes to provide evidence of continental drift.

- ✓3205.5.3 Identify the earth's layers.
- ✓3205.5.4 Identify geologic features associated with divergent, convergent, and transform plate boundaries.
- ✓3205.5.5 Identify the evidence for plate tectonics such as paleomagnetism, fossil record, continental boundaries, and hot spots.
- ✓3205.5.6 Describe how convection currents drive plate movement.
- ✓3205.5.7 Investigate the relationships among volcanoes, earthquake activity, and plate boundaries.
- ✓3205.5.8 Distinguish among reverse, normal, and strike-slip faults.
- ✓3205.5.9 Distinguish between an anticline and a syncline.
- ✓3205.5.10 Correlate plate movement by plotting the movement of plates over hot spots.

Standard 6 - Landforms

Conceptual Strand

Geologic processes sculpt the earth into landforms characterized by differences in topography.

Guiding Question

How do earth's interacting systems produce a variety of landforms?

Course Level Expectations

- CLE 3205.6.1** Investigate the hydrosphere and how changes in the hydrosphere affect various landforms.
- CLE 3205.6.2** Associate the surface processes responsible for various landforms.
- CLE 3205.6.3** Describe the characteristics of groundwater and explain how human activities affect groundwater quality.

Checks for Understanding (Formative/Summative Assessment)

- ✓3205.6.1 Recognize that the earth's landforms change over time.
- ✓3205.6.2 Illustrate the hydrologic cycle and distinguish among condensation, evaporation, precipitation, transpiration, groundwater, runoff, and surface water reservoirs.
- ✓3205.6.3 Compare the impact of water, wind, ice, and living things as agents of geologic change.
- ✓3205.6.4 Describe landforms associated with deserts, glaciers, shorelines, and rivers.
- ✓3205.6.5 Describe groundwater and its characteristics.
- ✓3205.6.6 Illustrate stream discharge using the Tennessee River or a local stream system.
- ✓3205.6.7 Describe the fluvial processes of erosion and deposition
- ✓3205.6.8 Describe the characteristics of a river in terms of its velocity, channel shape, depth, and discharge.
- ✓3205.6.9 Identify meanders, point bars, cut banks, and cutoffs on a map.
- ✓3205.6.10 Explain the processes of grain suspension, saltation, and settling to produce sedimentary deposits.
- ✓3205.6.11 Describe a floodplain and demonstrate how stream channels and natural levees function during flood conditions.

✓**3205.6.12** Describe delta formation.

✓**3205.6.13** Investigate the influence of landforms on man's cultural, social, and economic development.