

Utah State Office of Education

# core standards

*for*

# SCIENCE

The Utah State Board of Education, in January of 1984, established policy requiring the identification of specific core standards to be met by all K–12 students in order to graduate from Utah’s secondary schools. The Utah State Board of Education regularly updates the Utah Core Standards, while parents, teachers, and local school boards continue to control the curriculum choices that reflect local values.

The Utah Core Standards are aligned to scientifically based content standards. They drive high quality instruction through statewide comprehensive expectations for all students. The standards outline essential knowledge, concepts, and skills to be mastered at each grade level or within a critical content area. The standards provide a foundation for ensuring learning within the classroom.



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Larry K. Shumway, Ed.D. State Superintendent of Public Instruction



**Core Standards FOR**

# **Secondary Science**

**Earth Science, Biology, Chemistry, and Physics**

Adopted October 2012 (Earth Science) and April 2002 (Biology, Chemistry ,  
Physics) by Utah State Board of Education





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# Utah Science Core Curriculum

## Introduction

Science is a way of knowing, a process for gaining knowledge and understanding of the natural world. The Science Core Curriculum places emphasis on understanding and using skills. Students should be active learners. It is not enough for students to read about science; they must do science. They should observe, inquire, question, formulate and test hypotheses, analyze data, report, and evaluate findings. The students, as scientists, should have hands-on, active experiences throughout the instruction of the science curriculum.

The Science Core describes what students should know and be able to do at the end of each course. It was developed, critiqued, piloted, and revised by a community of Utah science teachers, university science educators, State Office of Education specialists, scientists, expert national consultants, and an advisory committee representing a wide diversity of people from the community. The Core reflects the current philosophy of science education that is expressed in national documents developed by the American Association for the Advancement of Science and the National Academies of Science. This Science Core has the endorsement of the Utah Science Teachers Association. The Core reflects high standards of achievement in science for all students.

## Organization of the Science Core

The Core is designed to help teachers organize and deliver instruction. Elements of the Core include the following:

- ❖ Each grade level begins with a brief course description.
- ❖ The **INTENDED LEARNING OUTCOMES (ILOs)** describe the goals for science skills and attitudes. They are found at the beginning of each grade, and are an integral part of the Core that should be included as part of instruction.
- ❖ The **SCIENCE BENCHMARKS** describe the science content students should know. Each grade level has three to five Science Benchmarks. The ILOs and Benchmarks intersect in the Standards, Objectives and Indicators.
- ❖ A **STANDARD** is a broad statement of what students are expected to understand. Several Objectives are listed under each Standard.
- ❖ An **OBJECTIVE** is a more focused description of what students need to know and be able to do at the completion of instruction. If students have mastered the Objectives associated with a given Standard, they are judged to have mastered that Standard at that grade level. Several Indicators are described for each Objective.
- ❖ An **INDICATOR** is a measurable or observable student action that enables one to judge whether a student has mastered a particular Objective. Indicators are not meant to be classroom activities, but they can help guide classroom instruction.
- ❖ **SCIENCE LANGUAGE STUDENTS SHOULD USE** is a list of terms that students and teachers should integrate into their normal daily conversations around science topics. These are **not** vocabulary lists for students to memorize.

## Seven Guidelines Used in Developing the Science Core

**Reflects the Nature of Science:** Science is a way of knowing, a process for gaining knowledge and understanding of the natural world. The Core is designed to produce an integrated set of Intended Learning Outcomes (ILOs) for students.

As described in these ILOs, students will:

- Use science process and thinking skills.
- Manifest science interests and attitudes.
- Understand important science concepts and principles.
- Communicate effectively using science language and reasoning.
- Demonstrate awareness of the social and historical aspects of science.
- Understand the nature of science.

**Coherent:** The Core has been designed so that, wherever possible, the science ideas taught within a particular grade level have a logical and natural connection with each other and with those of earlier grades. Efforts have also been made to select topics and skills that integrate well with one another and with other subject areas appropriate to grade level. In addition, there is an upward articulation of science concepts, skills, and content. This spiraling is intended to prepare students to understand and use more complex science concepts and skills as they advance through their science learning.

**Developmentally Appropriate:** The Core takes into account the psychological and social readiness of students. It builds from concrete experiences to more abstract understandings. The Core describes science language students should use that is appropriate to their grade level. A more extensive vocabulary should not be emphasized. In the past, many educators may have mistakenly thought that students understood abstract concepts (such as the nature of the atom) because they repeated appropriate names and vocabulary (such as “electron” and “neutron”). The Core resists the temptation to describe abstract concepts at inappropriate grade levels; rather, it focuses on providing experiences with concepts that students can explore and understand in depth to build a foundation for future science learning.

**Encourages Good Teaching Practices:** It is impossible to accomplish the full intent of the Core by lecturing and having students read from textbooks. The Science Core emphasizes student inquiry. Science process skills are central in each standard. Good science encourages students to gain knowledge by doing science: observing, questioning, exploring, making and testing hypotheses, comparing predictions, evaluating data, and communicating conclusions. The Core is designed to encourage instruction with students working in cooperative groups. Instruction should connect lessons with students’ daily lives. The Core directs experiential science instruction for all students, not just those who have traditionally succeeded in science classes.

**Comprehensive:** The Science Core does not cover all topics that have traditionally been in the science curriculum; however, it does provide a comprehensive background in science. By emphasizing depth rather than breadth, the Core seeks to empower students rather than intimidate them with a collection of isolated and forgettable facts. Teachers are free to add related concepts and skills, but they are expected to teach all the standards and objectives specified in the Core for their grade level.

**Useful and Relevant:** This curriculum relates directly to student needs and interests. It is grounded in the natural world in which we live. Relevance of science to other endeavors enables students to transfer skills gained from science instruction into their other school subjects and into their lives outside the classroom.

**Encourages Good Assessment Practices:** Student achievement of the standards and objectives in this Core is best assessed using a variety of assessment instruments. The purpose of an assessment should be clear to the teacher as it is planned, implemented, and evaluated. Performance tests are particularly appropriate to evaluate student mastery of science processes and problem-solving skills. Teachers should use a variety of classroom assessment approaches in conjunction with standard assessment instruments to inform their instruction. Sample test items, keyed to each Core Standard, may be located on the Utah Science Home Page <http://schools.utah.gov/curr/science/>. Observation of students engaged in science activities is highly recommended as a way to assess students' skills as well as attitudes in science. The nature of the questions posed by students provides important evidence of students' understanding and interest in science.

# Intended Learning Outcomes for High School Science

The Intended Learning Outcomes (ILOs) describe the skills and attitudes students should learn as a result of science instruction. They are an essential part of the Science Core Curriculum and provide teachers with a standard for evaluation of student learning in science. Instruction should include significant science experiences that lead to student understanding using the ILOs.

The main intent of science instruction in Utah is that students will value and use science as a process of obtaining knowledge based upon observable evidence.

By the end of science instruction in high school, students will be able to:

## 1. Use Science Process and Thinking Skills

- a. Observe objects, events and patterns and record both qualitative and quantitative information.
- b. Use comparisons to help understand observations and phenomena.
- c. Evaluate, sort, and sequence data according to given criteria.
- d. Select and use appropriate technological instruments to collect and analyze data.
- e. Plan and conduct experiments in which students may:
  - Identify a problem.
  - Formulate research questions and hypotheses.
  - Predict results of investigations based upon prior data.
  - Identify variables and describe the relationships between them.
  - Plan procedures to control independent variables.
  - Collect data on the dependent variable(s).
  - Select the appropriate format (e.g., graph, chart, diagram) and use it to summarize the data obtained.
  - Analyze data, check it for accuracy and construct reasonable conclusions.
  - Prepare written and oral reports of investigations.
- f. Distinguish between factual statements and inferences.
- g. Develop and use classification systems.
- h. Construct models, simulations and metaphors to describe and explain natural phenomena.
- i. Use mathematics as a precise method for showing relationships.
- j. Form alternative hypotheses to explain a problem.

## 2. Manifest Scientific Attitudes and Interests

- a. Voluntarily read and study books and other materials about science.
- b. Raise questions about objects, events and processes that can be answered through scientific investigation.
- c. Maintain an open and questioning mind toward ideas and alternative points of view.
- d. Accept responsibility for actively helping to resolve social, ethical and ecological problems related to science and technology.
- e. Evaluate scientifically related claims against available evidence.
- f. Reject pseudoscience as a source of scientific knowledge.

**3. Demonstrate Understanding of Science Concepts, Principles and Systems**

- a. Know and explain science information specified for the subject being studied.
- b. Distinguish between examples and non-examples of concepts that have been taught.
- c. Apply principles and concepts of science to explain various phenomena.
- d. Solve problems by applying science principles and procedures.

**4. Communicate Effectively Using Science Language and Reasoning**

- a. Provide relevant data to support their inferences and conclusions.
- b. Use precise scientific language in oral and written communication.
- c. Use proper English in oral and written reports.
- d. Use reference sources to obtain information and cite the sources.
- e. Use mathematical language and reasoning to communicate information.

**5. Demonstrate Awareness of Social and Historical Aspects of Science**

- a. Cite examples of how science affects human life.
- b. Give instances of how technological advances have influenced the progress of science and how science has influenced advances in technology.
- c. Understand the cumulative nature of scientific knowledge.
- d. Recognize contributions to science knowledge that have been made by both women and men.

**6. Demonstrate Understanding of the Nature of Science**

- a. Science is a way of knowing that is used by many people, not just scientists.
- b. Understand that science investigations use a variety of methods and do not always use the same set of procedures; understand that there is not just one "scientific method."
- c. Science findings are based upon evidence.
- d. Understand that science conclusions are tentative and therefore never final. Understandings based upon these conclusions are subject to revision in light of new evidence.
- e. Understand that scientific conclusions are based on the assumption that natural laws operate today as they did in the past and that they will continue to do so in the future.
- f. Understand the use of the term "theory" in science, and that the scientific community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.
- g. Understand that various disciplines of science are interrelated and share common rules of evidence to explain phenomena in the natural world.
- h. Understand that scientific inquiry is characterized by a common set of values that include logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results and honest and ethical reporting of findings. These values function as criteria in distinguishing between science and non-science.
- i. Understand that science and technology may raise ethical issues for which science, by itself, does not provide solutions.

Science language students should use:	generalize, conclude, hypothesis, theory, variable, measure, evidence, data, inference, infer, compare, predict, interpret, analyze, relate, calculate, observe, describe, classify, technology, experiment, investigation, tentative, assumption, ethical, replicability, precision, skeptical, methods of science
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## Earth Science Core Curriculum

Life and physical science content are integrated in a curriculum with two primary goals: (1) students will value and use science as a process of obtaining knowledge based on observable evidence, and (2) students' curiosity will be sustained as they develop the abilities associated with scientific inquiry. This course builds upon students' experience with integrated science in grades seven and eight and is the springboard course for success in biology, chemistry, geology, and physics.

### **Theme**

The theme for Earth Science is **systems**. The "Benchmarks" in the Earth Science Core emphasize "systems" as an organizing concept to understand life on Earth, geological change, and the interaction of atmosphere, hydrosphere, and biosphere. Earth Science provides students with an understanding of how the parts of a system through the study of the Earth's cycles and spheres. Earth's place in the universe as well its internal structure, tectonic plates, atmospheric processes, and hydrosphere are explored to help understand how Earth science interacts with society.

### **Inquiry**

Throughout this course students experience science as a way of knowing based on making observations, gathering data, designing experiments, making inferences, drawing conclusions, and communicating results. Students see that the science concepts apply to their lives and their society. This course will provide students with science skills to make informed and responsible decisions. Students will learn how to explain cosmic and global phenomena in terms of interactions of energy, matter, and life. These explorations range from the realization that all elements heavier than helium were made in stars to an understanding of how rain influences a desert ecosystem. Throughout the course, the instructor should reference the evidence that scientists used to reach their conclusions (hypotheses, theories, etc.). The students should be able to answer the question "How do we know?".

Good science instruction requires hands-on science investigations in which student inquiry is an important goal. Teachers should provide opportunities for **all** students to experience many things. Students in Earth Science should design and perform experiments and value inquiry as the fundamental scientific process. They should be encouraged to maintain an open and questioning mind to pose their own questions about objects, events, processes, and results. They should have the opportunity to plan and conduct their own experiments, and come to their own conclusions as they read, observe, compare, describe, infer, and draw conclusions. The results of their experiments need to be compared for reasonableness to multiple sources of information. It is important for students at this age to begin to formalize the processes of science and be able to identify the variables in an experiment.

### **Relevance**

Earth Science Core concepts should be integrated with concepts and skills from other curriculum areas. Reading, writing, and mathematics skills should be emphasized as integral to the instruction of science. Personal relevance of science in students' lives is an important part of helping students to value science and should be emphasized at this grade level. Developing students' writing skills in science should be an important part of science instruction in the ninth grade. Students should regularly write descriptions of their observations and experiments. Specific science literacy state standards can be found in the *Utah Core State Standards for English, Language Arts, & Literacy in History/Social Studies, Science and Technical Subjects for grades 6-12*.

Providing opportunities for students to gain insights into science related careers adds to the relevance of science learning. The topics in Earth Science introduce students to fundamental concepts related to

careers in astronomy, geology, meteorology, hydrology, physical geography, and ecology. This is an excellent opportunity for students to broaden their understanding of careers in these areas.

### **Vocabulary Terms in Earth Science:**

The Earth Science core highlights specific key concepts that are central to the understanding of the processes and themes of Earth's systems. These terms have been incorporated into the indicators and have been bolded and underlined. Students and teachers should integrate these terms into normal daily conversation around science topics. Terms that are repeated throughout multiple standards are highlighted in each standard the first time that they appear to support teachers as they utilize the core when planning their curriculum scope and sequence.

### **The Use of “i.e.” versus “e.g.” in the Core**

“i.e.” comes from the Latin *id est* and means “in other words” or “this and only this”. Used in the Utah Core Science Curricula, i.e. is interpreted as a learning expectation of all students. The exemplars following an i.e. should be clearly and unambiguously taught in every classroom. In the CRTs, exemplars included in an i.e. statement are assessed as expected knowledge or skills.

“e.g.” comes from the Latin *exempli gratia* and means “including” or “for example”. Used in the Utah Core Science Curricula, e.g. is interpreted as a few possible examples of a larger context or concept. The exemplars following an e.g. are not required, but serve as examples for teaching the specific indicator. Several equally valid exemplars of the same concept may also be taught. In the CRTs, exemplars included as part of an e.g. may serve as the seeds of a good item, but clarifying contextual information will be provided in the item.

### **Character**

Value for honesty, integrity, self-discipline, respect, responsibility, punctuality, dependability, courtesy, cooperation, consideration, and teamwork should be emphasized as an integral part of science learning. These relate to the care of living things, safety and concern for self and others, and environmental stewardship. Honesty in all aspects of research, experimentation, data collection, and reporting is an essential component of science.

### **Resources for Instruction**

This Core was designed using the American Association for the Advancement of Science's *Project 2061: Benchmarks for Science Literacy* and the National Academy of Science's *National Science Education Standards* as guides to determine appropriate content and skills.

The Earth Science Core has three online resources designed to help with classroom instruction. These resources include the *Sci-ber Text*, an electronic science textbook; web resources listed by Core objective; and the science test item pool. This pool includes multiple-choice questions, performance tasks, and interpretive items aligned to the standards and objectives of the Core. These resources are all aligned to the Core and available on the Utah Science Home Page at <http://schools.utah.gov/CURR/science/default.aspx>

### **Safety Precautions**

The hands-on nature of science learning increases the need for teachers to use appropriate precautions in the classroom and field. Proper handling and disposal of chemicals is crucial for a safe classroom.

### **Appropriate Use of Living Things in the Science Classroom**

It is important to maintain a safe, humane environment for animals in the classroom. Field activities should be well thought out and use appropriate and safe practices. Student collections should be done under the guidance of the teacher with attention to the impact on the environment. The number and size of the samples taken for the collections should be considered in light of the educational benefit. Some

organisms should not be taken from the environment, but rather observed and described using photographs, drawings, or written descriptions to be included in the student's collection. Teachers must adhere to the published guidelines for the proper use of animals, equipment, and chemicals in the classroom. These guidelines are available on the Utah Science Home Page.

### **The Most Important Goal**

Science instruction should cultivate and build on students' curiosity and sense of wonder. Effective science instruction engages students in enjoyable learning experiences. Science instruction should be as thrilling an experience for a student as opening a rock and seeing a fossil, determining the quality of a water sample by watching the colors change in a chemical reaction, or observing the consistent sequence of color in a rainbow. Science is not just for those who have traditionally succeeded in the subject, and it is not just for those who will choose science-related careers. In a world of rapidly expanding knowledge and technology, all students must gain the skills they will need to understand and function responsibly and successfully in the world. The Core encourages instruction that provides skills in a context that enables students to experience the joy of doing science.

## Earth Science Core Curriculum

***Standard 1: Students will understand the scientific evidence that supports theories that explain how the universe and the solar system developed. They will compare Earth to other objects in the solar system.***

**Objective 1: Describe both the big bang theory of universe formation and the nebular theory of solar system formation and evidence supporting them.**

- a. Identify the scientific evidence for the age of the **solar system** (4.6 billion years), including Earth (e.g., radioactive decay).
- b. Describe the **big bang theory** and the evidence that supports this theory (e.g., cosmic background radiation, abundance of elements, distance/redshift relation for galaxies).
- c. Describe the **nebular theory** of solar system formation and the evidence supporting it (e.g., solar system structure due to gravity, motion and temperature; composition and age of meteorites; observations of newly forming stars).
- d. Explain that **heavy elements** found on Earth are formed in stars.
- e. Investigate and report how science has changed the accepted ideas regarding the nature of the universe throughout history.
- f. Provide an example of how technology has helped scientists investigate the universe.

**Objective 2: Analyze Earth as part of the solar system, which is part of the Milky Way galaxy.**

- a. Relate the **composition** of objects in the solar system to their distance from the Sun.
- b. Compare the size of the solar system to the **Milky Way galaxy**.
- c. Compare the size and **scale** of objects within the solar system.
- d. Evaluate the conditions that currently support life on Earth (**biosphere**) and compare them to the conditions that exist on other planets and moons in the solar system (e.g., atmosphere, hydrosphere, geosphere, amounts of incoming solar energy, habitable zone).

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***Standard 2: Students will understand Earth’s internal structure and the dynamic nature of the tectonic plates that form its surface.***

**Objective 1: Evaluate the source of Earth’s internal heat and the evidence of Earth’s internal structure.**

- a. Identify that **radioactive decay** and **heat of formation** are the sources of Earth’s internal heat.
- b. Trace the lines of scientific evidence (e.g., seismic studies, composition of meteorites, and samples of the crust and mantle) that led to the inference that Earth’s **core**, **mantle**, and **crust** are separated based on **composition**.
- c. Trace the lines of scientific evidence that led to the inference that Earth’s **lithosphere**, **asthenosphere**, **mesosphere**, **outer core**, and **inner core** are separated based on **physical properties**.
- d. Model how **convection** currents help distribute heat within the mantle.

**Objective 2: Describe the development of the current theory of plate tectonics and the evidence that supports this theory.**

- a. Explain Alfred Wegener’s **continental drift hypothesis**, his evidence (e.g., fossil record, ancient climates, geometric fit of continents), and why it was not accepted in his time.
- b. Cite examples of how the **geologic record** preserves evidence of past change.
- c. Establish the importance of the discovery of **mid-ocean ridges**, **oceanic trenches**, and **magnetic striping** of the sea floor to the development of the modern theory of **plate tectonics**.
- d. Explain how **mantle plumes** (hot spots) provide evidence for the rate and direction of tectonic plate motion.
- e. Organize and evaluate the evidence for the current theory of plate tectonics: **sea floor spreading**, age of sea floor, distribution of **earthquakes** and **volcanoes**.

**Objective 3: Demonstrate how the motion of tectonic plates affects Earth and living things.**

- a. Describe a **lithospheric plate** and identify the major plates of the Earth.
- b. Describe how earthquakes and volcanoes transfer energy from Earth’s interior to the surface (e.g., seismic waves transfer mechanical energy, flowing magma transfers heat and mechanical energy).
- c. Model the factors that cause **tectonic plates** to move (e.g., gravity, density, convection).
- d. Model tectonic plate movement and compare the results of plate movement along **convergent**, **divergent**, and **transform boundaries** (e.g., mountain building, volcanoes, earthquakes, mid-ocean ridges, oceanic trenches).
- e. Design, build, and test a model that investigates local geologic processes (e.g., mudslides, earthquakes, flooding, erosion) and the possible effects on human-engineered structures (e.g., dams, homes, bridges, roads).

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***Standard 3: Students will understand the atmospheric processes that support life and cause weather and climate.***

**Objective 1: Relate how energy from the Sun drives atmospheric processes and how atmospheric currents transport matter and transfer energy.**

- a. Compare and contrast the amount of energy coming from the Sun that is **reflected**, **absorbed** or **scattered** by the **atmosphere**, oceans, and land masses.
- b. Construct a model that demonstrates how the **greenhouse effect** contributes to atmospheric energy.
- c. Conduct an investigation on how the tilt of Earth's axis causes variations in the intensity and duration of sunlight striking Earth.
- d. Explain how uneven heating of Earth's atmosphere at the equator and polar regions combined with the **Coriolis effect** create an atmospheric circulation system including, **Hadley cells**, **trade winds**, and **prevailing westerlies**, that moves heat energy around Earth.
- e. Explain how the presence of **ozone** in the **stratosphere** is beneficial to life, while ozone in the **troposphere** is considered an **air pollutant**.

**Objective 2: Describe elements of weather and the factors that cause them to vary from day to day.**

- a. Identify the elements of **weather** and the instruments used to measure them (e.g., temperature—thermometer; precipitation—rain gauge or Doppler radar; humidity—hygrometer; air pressure—barometer; wind—anemometer; cloud coverage—satellite imaging).
- b. Describe conditions that give rise to severe weather phenomena (e.g., thunderstorms, tornados, hurricanes, El Niño/La Niña).
- c. Explain a difference between a **low pressure system** and a **high pressure system**, including the weather associated with them.
- d. Diagram and describe **cold**, **warm**, **occluded**, and **stationary boundaries** (weather fronts) between **air masses**.
- e. Design and conduct a weather investigation, use an appropriate display of the data, and interpret the observations and data.

**Objective 3: Examine the natural and human-caused processes that cause Earth's climate to change over intervals of time ranging from decades to millennia.**

- a. Explain differences between **weather** and **climate** and the methods used to investigate evidence for changes in climate (e.g., ice core sampling, tree rings, historical temperature measurements, changes in the extent of alpine glaciers, changes in the extent of Arctic sea ice).
- b. Explain how Earth's climate has changed over time and describe the natural causes for these changes (e.g., Milankovitch cycles, solar fluctuations, plate tectonics).
- c. Describe how human activity influences the **carbon cycle** and may contribute to climate change.
- d. Explain the differences between air pollution and climate change and how these are related to society's use of **fossil fuels**.

- e. Investigate the current and potential consequences of **climate change** (e.g., ocean acidification, sea level rise, desertification, habitat loss) on **ecosystems**, including human communities.

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***Standard 4: Students will understand the dynamics of the hydrosphere.***

**Objective 1: Characterize the water cycle in terms of its reservoirs, water movement among reservoirs and how water has been recycled throughout time.**

- a. Identify oceans, lakes, running water, frozen water, ground water, and atmospheric moisture as the **reservoirs** of Earth's **water cycle**, and graph or chart the relative amounts of water in each.
- b. Describe how the processes of **evaporation**, **condensation**, **precipitation**, **surface runoff**, **ground infiltration** and **transpiration** contribute to the cycling of water through Earth's reservoirs.
- c. Model the **natural purification** of water as it moves through the water cycle and compare natural purification to processes used in local sewage treatment plants.

**Objective 2: Analyze the characteristics and importance of freshwater found on Earth's surface and its effect on living systems.**

- a. Investigate the properties of water: exists in all three states, dissolves many substances, exhibits **adhesion** and **cohesion**, density of solid vs. liquid water.
- b. Plan and conduct an experiment to investigate **biotic** and **abiotic** factors that affect freshwater **ecosystems**.
- c. Using data collected from local water systems, evaluate water quality and conclude how pollution can make water unavailable or unsuitable for life.
- d. Research and report how communities manage water resources (e.g., distribution, shortages, quality, flood control) to address **social**, **economic**, and **environmental** concerns.

**Objective 3: Analyze the physical, chemical, and biological dynamics of the oceans and the flow of energy through the oceans.**

- a. Research how the oceans formed from **outgassing** by **volcanoes** and ice from **comets**.
- b. Investigate how **salinity**, temperature, and pressure at different depths and locations in oceans and lakes affect saltwater ecosystems.
- c. Design and conduct an experiment comparing **chemical properties** (e.g., chemical composition, percent salinity) and **physical properties** (e.g., density, freezing point depression) of freshwater samples to saltwater samples from different sources.
- d. Model **energy flow** in the physical dynamics of oceans (e.g., wave action, deep ocean tides circulation, surface currents, land and sea breezes, El Niño, upwellings).
- e. Evaluate the impact of human activities (e.g., sediment, pollution, overfishing) on ocean systems.

Science language students should use:	Please note that Earth Science terminology has been incorporated into the indicators above and have been bolded and underlined. Students and teachers should integrate these terms into normal daily conversations around science topics.
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*Standard 5: Students will understand how Earth science interacts with society.*

**Objective 1: Characterize Earth as a changing and complex system of interacting spheres.**

- a. Illustrate how energy flowing and matter cycling within Earth's **biosphere**, **geosphere**, **atmosphere**, and **hydrosphere** give rise to processes that shape Earth.
- b. Explain how Earth's systems are dynamic and continually react to natural and human-caused changes.
- c. Explain how technological advances lead to increased human knowledge (e.g., satellite imaging, deep sea ocean probes, seismic sensors, weather radar systems) and ability to predict how changes affect Earth's systems.
- d. Design and conduct an experiment that investigates how Earth's **biosphere**, **geosphere**, **atmosphere**, or **hydrosphere** reacts to human-caused change.
- e. Research and report on how scientists study **feedback loops** to inform the public about Earth's interacting systems.

**Objective 2: Describe how humans depend on Earth's resources.**

- a. Investigate how Earth's resources (e.g., mineral resources, petroleum resources, alternative energy resources, water resources, soil and agricultural resources) are distributed across the state, the country, and the world.
- b. Research and report on how human populations depend on **Earth resources** for sustenance and how changing conditions over time have affected these resources (e.g., water pollution, air pollution, increases in population).
- c. Predict how resource development and use alters Earth systems (e.g., water reservoirs, alternative energy sources, wildlife preserves).
- d. Describe the role of scientists in providing data that informs the discussion of Earth resource use.
- e. Justify the claim that **Earth science literacy** can help the public make informed choices related to the extraction and use of natural resources.

**Objective 3: Indicate how natural hazards pose risks to humans.**

- a. Identify and describe **natural hazards** that occur locally (e.g., wildfires, landslides, earthquakes, floods, drought) and globally (e.g., volcanoes, tsunamis, hurricanes).
- b. Evaluate and give examples of human activities that can contribute to the frequency and intensity of some natural hazards (e.g., construction that may increase erosion, human causes of wildfires, climate change).
- c. Document how scientists use technology to continually improve estimates of when and where natural hazards occur.
- d. Investigate and report how **social**, **economic**, and **environmental** issues affect decisions about human-engineered structures (e.g., dams, homes, bridges, roads).

Science language students should use:	Please note that Earth Science terminology has been incorporated into the indicators above and have been bolded and underlined. Students and teachers should integrate these terms into normal daily conversations around science topics.
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## Biology Core Curriculum

The Biology Core Curriculum has two primary goals: (1) students will value and use science as a process of obtaining knowledge based on observable evidence, and (2) students' curiosity will be sustained as they develop and refine the abilities associated with scientific inquiry.

### Theme

The Biology Core has three major concepts for the focus of instruction: (1) the structures in all living things occur as a result of necessary functions. (2) Interactions of organisms in an environment are determined by the biotic and abiotic components of the environment. (3) Evolution of species occurs over time and is related to the environment in which the species live.

### Inquiry

Biology students should design and perform experiments, and value inquiry as the fundamental scientific process. They should be encouraged to maintain an open and questioning mind, to pose their own questions about objects, events, processes, and results. They should have the opportunity to plan and conduct their own experiments, and come to their own conclusions as they read, observe, compare, describe, infer, and draw conclusions. The results of their experiments need to be compared for reasonableness to multiple sources of information. They should be encouraged to use reasoning as they apply biology concepts to their lives.

### Scope

Not all possible biology topics are specified in the Core. Teachers may enhance their individual classes as they see opportunities to include more topics or more depth. The Biology Core is intended for teachers to help students understand basic biology concepts, develop scientific habits, and experience the process of scientific investigations. Good instruction requires hands-on investigations in which student inquiry is an important goal. Teachers should provide opportunities for **all** students to experience many things. Laboratory investigations should be frequent and meaningful components of biology instruction. Teachers should help students plan and conduct experiments in which they:

- ◆ Identify a problem.
- ◆ Formulate a research question and hypothesis.
- ◆ Identify variables and describe relationships between them.
- ◆ Plan procedures to control independent variables.
- ◆ Collect data on the dependent variable(s).
- ◆ Select the appropriate format (e.g., graph, chart, diagram) to summarize data obtained.
- ◆ Analyze data, check for accuracy, and construct reasonable conclusions.
- ◆ Prepare written and oral reports of investigations.

Students should enjoy science as a process of discovering and understanding the physical world.

### Relevance

Biology Core concepts should be integrated with concepts and skills from other curriculum areas. Reading, writing, and mathematics skills should be emphasized as integral to the instruction of science. Personal relevance of science in students' lives is an important part of helping students to value science and should be emphasized at this grade level. Developing students' writing skills in science should be an important part of science instruction in biology. Students should regularly write descriptions of their observations and experiments. Students should regularly write descriptions of their observations and experiments. Specific science literacy state

standards can be found in the *Utah Core State Standards for English, Language Arts, & Literacy in History/Social Studies, Science and Technical Subjects for grades 6-12*.

Providing opportunities for students to gain insights into science related careers adds to the relevance of science learning. Biology provides students with an opportunity to investigate careers in genetics, biotechnology, wildlife management, environmental science, and many fields of medicine.

### **Character**

Value for honesty, integrity, self-discipline, respect, responsibility, punctuality, dependability, courtesy, cooperation, consideration, and teamwork should be emphasized as an integral part of science learning. These relate to the care of living things, safety and concern for self and others, and environmental stewardship. Honesty in all aspects of research, experimentation, data collection, and reporting is an essential component of science.

### **The Use of “i.e.” versus “e.g.” in the Core**

“i.e.” comes from the Latin *id est* and means “in other words” or “this and only this”. Used in the Utah Core Science Curricula, i.e. is interpreted as a learning expectation of all students. The exemplars following an i.e. should be clearly and unambiguously taught in every classroom. In the CRTs, exemplars included in an i.e. statement are assessed as expected knowledge or skills.

“e.g.” comes from the Latin *exempli gratia* and means “including” or “for example”. Used in the Utah Core Science Curricula, e.g. is interpreted as a few possible examples of a larger context or concept. The exemplars following an e.g. are not required, but serve as examples for teaching the specific indicator. Several equally valid exemplars of the same concept may also be taught. In the CRTs, exemplars included as part of an e.g. may serve as the seeds of a good item, but clarifying contextual information will be provided in the item.

### **Resources for Instruction**

This Core was designed using the American Association for the Advancement of Science’s *Project 2061: Benchmarks For Science Literacy* and the National Academy of Science’s *National Science Education Standards* as guides to determine appropriate content and skills.

The Biology Core has many online resources designed to help with classroom instruction. The Utah Science Home Page at <http://schools.utah.gov/CURR/science/default.aspx> is an ongoing report of resources available and aligned to the Biology Core Curriculum.

### **Safety Precautions**

The hands-on nature of science learning increases the need for teachers to use appropriate precautions in the classroom and field. Proper handling and disposal of chemicals is crucial for a safe classroom. The chemistry described in biology can be accomplished using safe household chemicals and microchemistry techniques. It is important that all students understand the rules for a safe classroom.

### **Appropriate Use of Living Things in the Science Classroom**

It is important to maintain a safe, humane environment for animals in the classroom. Field activities should be well thought out and use appropriate and safe practices. Student collections should be done under the guidance of the teacher with attention to the impact on the environment. The number and size of the samples taken for the collections should be considered in light of the educational benefit. Some organisms should not be taken from the environment, but rather observed and described using photographs, drawings, or written descriptions to be included in the student’s collection. Teachers must

adhere to the published guidelines for the proper use of animals, equipment, and chemicals in the classroom. These guidelines are available on the Utah Science Home Page.

### **The Most Important Goal**

Science instruction should cultivate and build on students' curiosity and sense of wonder. Effective science instruction engages students in enjoyable learning experiences. Science instruction should be as thrilling an experience for a student as opening a rock and seeing a fossil, tracing and interpreting a pedigree, or observing the affects of some chemical on the heartbeat of daphnia. Science is not just for those who have traditionally succeeded in the subject, and it is not just for those who will choose science-related careers. In a world of rapidly expanding knowledge and technology, all students must gain the skills they will need to understand and function responsibly and successfully in the world. The Core provides skills in a context that enables students to experience the joy of doing science.

## Biology Core Curriculum

### Science Benchmark

Ecosystems are shaped by interactions among living organisms and their physical environment. Ecosystems change constantly, either staying in a state of dynamic balance or shifting to a new state of balance. Matter cycles in ecosystems, and energy flows from outside sources through the system. Humans are part of ecosystems and can deliberately or inadvertently alter an ecosystem.

### **STANDARD 1: Students will understand that living organisms interact with one another and their environment.**

**Objective 1:** Summarize how energy flows through an ecosystem.

- Arrange components of a food chain according to energy flow.
- Compare the quantity of energy in the steps of an energy pyramid.
- Describe strategies used by organisms to balance the energy expended to obtain food to the energy gained from the food (e.g., migration to areas of seasonal abundance, switching type of prey based upon availability, hibernation or dormancy).
- Compare the relative energy output expended by an organism in obtaining food to the energy gained from the food (e.g., hummingbird - energy expended hovering at a flower compared to the amount of energy gained from the nectar, coyote - chasing mice to the energy gained from catching one, energy expended in migration of birds to a location with seasonal abundance compared to energy gained by staying in a cold climate with limited food).
- Research food production in various parts of the world (e.g., industrialized societies' greater use of fossil fuel in food production, human health related to food product).

**Objective 2:** Explain relationships between matter cycles and organisms.

- Use diagrams to trace the movement of matter through a cycle (e.g., carbon, oxygen, nitrogen, water) in a variety of biological communities and ecosystems.
- Explain how water is a limiting factor in various ecosystems.
- Distinguish between inference and evidence in a newspaper, magazine, journal, or Internet article that addresses an issue related to human impact on cycles of matter in an ecosystem and determine the bias in the article.
- Evaluate the impact of personal choices in relation to the cycling of matter within an ecosystem (e.g., impact of automobiles on the carbon cycle, impact on landfills of processed and packaged foods).

**Objective 3:** Describe how interactions among organisms and their environment help shape ecosystems.

- Categorize relationships among living things according to predator-prey, competition, and symbiosis.
- Formulate and test a hypothesis specific to the effect of changing one variable upon another in a small ecosystem.
- Use data to interpret interactions among biotic and abiotic factors (e.g., pH, temperature, precipitation, populations, diversity) within an ecosystem.
- Investigate an ecosystem using methods of science to gather quantitative and qualitative data that describe the ecosystem in detail.
- Research and evaluate local and global practices that affect ecosystems.

Science language students should use:	predator-prey, symbiosis, competition, ecosystem, carbon cycle, nitrogen cycle, oxygen cycle, population, diversity, energy pyramid, consumers, producers, limiting factor, competition, decomposers, food chain, biotic, abiotic, community, variable, evidence, inference, quantitative, qualitative
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Science Benchmark

Cells are the basic unit of life. All living things are composed of one or more cells that come from preexisting cells. Cells perform a variety of functions necessary to maintain homeostasis and life. The structure and function of a cell determines the cell's role in an organism. Living cells are composed of chemical elements and molecules that form large, complex molecules. These molecules form the basis for the structure and function of cells.

**STANDARD 2: Students will understand that all organisms are composed of one or more cells that come from preexisting cells, are made of molecules, and perform life functions.**

**Objective 1:** Describe the fundamental chemistry of living cells.

- a. List the major chemical elements in cells (e.g., carbon, hydrogen, nitrogen, oxygen, phosphorous, sulfur).
- b. Identify the function of the four major macromolecules (e.g., carbohydrates, proteins, lipids, nucleic acids).
- c. Explain how the properties of water (e.g., cohesion, adhesion, heat capacity, solvent properties) contribute to the maintenance of cells and living organisms.
- d. Explain the role of enzymes in cell chemistry.

**Objective 2:** Describe the flow of energy and matter in cellular function.

- a. Distinguish between autotrophic and heterotrophic cells.
- b. Illustrate the cycling of matter and the flow of energy through photosynthesis (e.g., using light energy to combine CO<sub>2</sub> and H<sub>2</sub>O to produce oxygen and sugars) and respiration (e.g., releasing energy from sugar and O<sub>2</sub> to produce CO<sub>2</sub> and H<sub>2</sub>O).
- c. Measure the production of one or more of the products of either photosynthesis or respiration.

**Objective 3:** Investigate the structure and function of cells and cell parts.

- a. Explain how cells divide from existing cells through the process of mitosis.
- b. Describe cell theory and relate the nature of science to the development of cell theory (e.g., built upon previous knowledge, use of increasingly more sophisticated technology).
- c. Describe how the transport of materials in and out of cells enables cells to maintain homeostasis (e.g., osmosis, diffusion, active transport).
- d. Describe the relationship between the organelles in a cell and the functions of that cell.
- e. Experiment with microorganisms and/or plants to investigate growth and reproduction.

Science language students should use:	organelles, photosynthesis, respiration, cellular respiration, osmosis, diffusion, active transport, homeostasis, cell theory, organic, carbohydrate, fermentation, protein, lipid, nucleic acid, enzyme, chlorophyll, cell membrane, nucleus, cell wall, solvent, solute, adhesion, cohesion, microorganism, mitosis
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Science Benchmark

Structure relates to function. Organs and organ systems function together to provide homeostasis in organisms. The functioning of organs depends upon multiple organ systems.

**STANDARD 3: Students will understand the relationship between structure and function of organs and organ systems.**

**Objective 1:** Describe the structure and function of organs.

- a. Diagram and label the structure of the primary components of representative organs in plants and animals (e.g., heart - muscle tissue, valves and chambers; lung - trachea, bronchial, alveoli; leaf - veins, stomata; stem - xylem, phloem, cambium; root - tip, elongation, hairs; skin - layers, sweat glands, oil glands, hair follicles; ovaries - ova, follicles, corpus luteum).
- b. Describe the function of various organs (e.g. heart, lungs, skin, leaf, stem, root, ovary).
- c. Relate the structure of organs to the function of organs.
- d. Compare the structure and function of organs in one organism to the structure and function of organs in another organism.
- e. Research and report on technological developments related to organs.

**Objective 2:** Describe the relationship between structure and function of organ systems in plants and animals.

- a. Relate the function of an organ to the function of an organ system.
- b. Describe the structure and function of various organ systems (e.g., digestion, respiration, circulation, protection and support, nervous) and how these systems contribute to homeostasis of the organism.
- c. Examine the relationships of organ systems within an organism (e.g., respiration to circulation, leaves to roots) and describe the relationship of structure to function in the relationship.
- d. Relate the tissues that make up organs to the structure and function of the organ.
- e. Compare the structure and function of organ systems in one organism to the structure and function in another organism (e.g., chicken to sheep digestive system; fern to peach reproductive system).

Science language  
students should use:

organ, organ system, organism, hormonal modification, stomata, tissue, homeostasis, structure, function

Science Benchmark

Information passed from parent to offspring is coded in DNA (deoxyribonucleic acid) molecules. The fundamental DNA structure is the same for all living things; the sequence of DNA differs between each organism and each species. Changes in the DNA sequence may alter genetic expression. The genetic information in DNA provides the instructions for assembling protein molecules in cells. The code used is virtually the same for all organisms.

There are predictable patterns of inheritance. Sexual reproduction increases the genetic variation of a species. Asexual reproduction produces offspring that have the same genetic code as the parent.

**STANDARD 4: Students will understand that genetic information coded in DNA is passed from parents to offspring by sexual and asexual reproduction. The basic structure of DNA is the same in all living things. Changes in DNA may alter genetic expression.**

**Objective 1:** Compare sexual and asexual reproduction.

- a. Explain the significance of meiosis and fertilization in genetic variation.
- b. Compare the advantages/disadvantages of sexual and asexual reproduction to survival of species.
- c. Formulate, defend, and support a perspective of a bioethical issue related to intentional or unintentional chromosomal mutations.

**Objective 2:** Predict and interpret patterns of inheritance in sexually reproducing organisms.

- a. Explain Mendel's laws of segregation and independent assortment and their role in genetic inheritance.
- b. Demonstrate possible results of recombination in sexually reproducing organisms using one or two pairs of contrasting traits in the following crosses: dominance/recessive, incomplete dominance, codominance, and sex-linked traits.
- c. Relate Mendelian principles to modern-day practice of plant and animal breeding.
- d. Analyze bioethical issues and consider the role of science in determining public policy.

**Objective 3:** Explain how the structure and replication of DNA are essential to heredity and protein synthesis.

- a. Use a model to describe the structure of DNA.
- b. Explain the importance of DNA replication in cell reproduction.
- c. Summarize how genetic information encoded in DNA provides instructions for assembling protein molecules.
- d. Describe how mutations may affect genetic expression and cite examples of mutagens.
- e. Relate the historical events that led to our present understanding of DNA to the cumulative nature of science knowledge and technology.
- f. Research, report, and debate genetic technologies that may improve the quality of life (e.g., genetic engineering, cloning, gene splicing).

Science language students should use:	DNA, replication, fertilization, dominant trait, recessive trait, genetic engineering, gene splicing, phenotype, genotype, sexual reproduction, asexual reproduction, chromosome, gene, mutation, cloning, inheritance, bioethics, pedigree, meiosis
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## Science Benchmark

Evolution is central to modern science's understanding of the living world. The basic idea of biological evolution is that Earth's present day species developed from earlier species. Evolutionary processes allow some species to survive with little or no change, some to die out altogether, and other species to change, giving rise to a greater diversity of species. Science distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as science strives for explanations of the world.

### **STANDARD 5: Students will understand that biological diversity is a result of evolutionary processes.**

**Objective 1:** Relate principles of evolution to biological diversity.

- a. Describe the effects of environmental factors on natural selection.
- b. Relate genetic variability to a species' potential for adaptation to a changing environment.
- c. Relate reproductive isolation to speciation.
- d. Compare selective breeding to natural selection and relate the differences to agricultural practices.

**Objective 2:** Cite evidence for changes in populations over time and use concepts of evolution to explain these changes.

- a. Cite evidence that supports biological evolution over time (e.g., geologic and fossil records, chemical mechanisms, DNA structural similarities, homologous and vestigial structures).
- b. Identify the role of mutation and recombination in evolution.
- c. Relate the nature of science to the historical development of the theory of evolution.
- d. Distinguish between observations and inferences in making interpretations related to evolution (e.g., observed similarities and differences in the beaks of Galapagos finches leads to the inference that they evolved from a common ancestor; observed similarities and differences in the structures of birds and reptiles leads to the inference that birds evolved from reptiles).
- e. Review a scientific article and identify the research methods used to gather evidence that documents the evolution of a species.

**Objective 3:** Classify organisms into a hierarchy of groups based on similarities that reflect their evolutionary relationships.

- a. Classify organisms using a classification tool such as a key or field guide.
- b. Generalize criteria used for classification of organisms (e.g., dichotomy, structure, broad to specific).
- c. Explain how evolutionary relationships are related to classification systems.
- d. Justify the ongoing changes to classification schemes used in biology.

Science language students should use:	evolution, fossil record, geologic record, molecular, homologous, vestigial structures, mutation, recombination, hierarchy, classification scheme, theory, natural selection, adaptation, evidence, inference, speciation, biodiversity, taxonomy, kingdom, virus, protist, fungi, plant, animal, dichotomy
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# Chemistry Core Curriculum

The Chemistry Core Curriculum has two primary goals: (1) students will value and use science as a process of obtaining knowledge based on observable evidence, and (2) students' curiosity will be sustained as they develop the abilities associated with scientific inquiry.

## Theme

Chemistry is organized around major concepts of matter, structure, energy, and change. The "Benchmarks" in the chemistry Core emphasize the principles and laws that describe the conservation of matter, changes in the structure of matter, and changes in energy. Substances can be described by their chemical structure or properties. Substances are made of atoms and these atoms can form molecules. The properties of water are very different from the properties of hydrogen or oxygen of which it is composed. When parts come together, the whole often has properties that are very different from its parts. The formation of compounds results in a great diversity of matter from a limited number of elements. When matter combines, energy is absorbed or released and matter is rearranged to make new substances with new properties.

The purpose of the Utah Chemistry Core Curriculum is to provide the minimum standards for all students to achieve basic scientific literacy in chemistry. The Core is written with the understanding that individual teachers may choose additional content and activities to meet the needs and interests of their own students.

## Scope

Not all possible chemistry topics are specified in the Core. Teachers may enhance their individual classes as they see opportunities to include more topics or more depth. The Chemistry Core is intended for teachers to help students understand basic chemistry concepts, develop scientific habits, and experience the process of scientific investigations. Good instruction requires hands-on investigations in which student inquiry is an important goal. Teachers should provide opportunities for **all** students to experience many things. Laboratory investigations should be frequent and meaningful components of chemistry instruction. Teachers should help students plan and conduct experiments in which they:

- ◆ Identify a problem.
- ◆ Formulate a research question and hypothesis.
- ◆ Identify variables and describe relationships between them.
- ◆ Plan procedures to control independent variables.
- ◆ Collect data on the dependent variable(s).
- ◆ Select the appropriate format (e.g., graph, chart, diagram) to summarize data obtained.
- ◆ Analyze data, check for accuracy, and construct reasonable conclusions.
- ◆ Prepare written and oral reports of investigations.

Students should enjoy science as a process of discovering and understanding the physical world.

## Inquiry

Chemistry students should design and perform experiments, and value inquiry as the fundamental scientific process. Instruction should encourage students to maintain an open and questioning mind to pose their own questions about objects, events, processes, and results. They should have the opportunity to plan and conduct their own experiments, and come to their own conclusions as they read, observe, compare, describe, infer, and draw conclusions. The results of their experiments need to be compared for reasonableness to multiple sources of information. It is important for students at this age to begin to formalize the processes of science and be able to identify the variables in a formal experiment.

## **Relevance**

Chemistry Core concepts should be integrated with concepts and skills from other curriculum areas. Reading, writing, and mathematics skills should be emphasized as integral to the instruction of science. Personal relevance of science in students' lives is an important part of helping students to value science and should be emphasized at this grade level. Developing students' writing skills in science should be an important part of science instruction in chemistry. Students should regularly write descriptions of their observations and experiments. . Specific science literacy state standards can be found in the *Utah Core State Standards for English, Language Arts, & Literacy in History/Social Studies, Science and Technical Subjects for grades 6-12*.

Providing opportunities for students to gain insights into science related careers adds to the relevance of science learning. Chemistry provides students with an opportunity to investigate careers in chemistry, environmental science, food science, atomic energy, engineering, and medicine.

## **Character**

Value for honesty, integrity, self-discipline, respect, responsibility, punctuality, dependability, courtesy, cooperation, consideration, and teamwork should be emphasized as an integral part of science learning. These relate to the care of living things, safety and concern for self and others, and environmental stewardship. Honesty in all aspects of research, experimentation, data collection, and reporting is an essential component of science.

## **The Use of “i.e.” versus “e.g.” in the Core**

“i.e.” comes from the Latin *id est* and means “in other words” or “this and only this”. Used in the Utah Core Science Curricula, i.e. is interpreted as a learning expectation of all students. The exemplars following an i.e. should be clearly and unambiguously taught in every classroom. In the CRTs, exemplars included in an i.e. statement are assessed as expected knowledge or skills.

“e.g.” comes from the Latin *exempli gratia* and means “including” or “for example”. Used in the Utah Core Science Curricula, e.g. is interpreted as a few possible examples of a larger context or concept. The exemplars following an e.g. are not required, but serve as examples for teaching the specific indicator. Several equally valid exemplars of the same concept may also be taught. In the CRTs, exemplars included as part of an e.g. may serve as the seeds of a good item, but clarifying contextual information will be provided in the item.

## **Resources for Instruction**

This Core was designed using the American Association for the Advancement of Science's *Project 2061: Benchmarks For Science Literacy* and the National Academy of Science's *National Science Education Standards* as guides to determine appropriate content and skills.

The Chemistry Core has many online resources designed to help with classroom instruction. The Utah Science Home Page at <http://schools.utah.gov/CURR/science/default.aspx> is an ongoing report of resources available and aligned to the Chemistry Core Curriculum.

## **Safety Precautions and Appropriate Use and Disposal of Chemical**

The hands-on nature of science learning increases the need for teachers to use appropriate precautions in the classroom, laboratory, and field. Proper handling and disposal of chemicals is crucial for safety of students and teacher. Prior to students working in the laboratory they should be required to demonstrate their understanding of safe laboratory practices. It is recommended that teachers use microchemistry techniques where appropriate. It is important that all students understand the rules for a safe classroom and laboratory. Field activities should be well thought out and use appropriate and safe

practices. Teachers must adhere to the published guidelines for the proper use and disposal of chemicals in the classroom. These guidelines are available on the Utah Science Home Page at <http://schools.utah.gov/CURR/science/default.aspx>.

### **The Most Important Goal**

Science instruction should cultivate and build on students' curiosity and sense of wonder. Effective science instruction engages students in enjoyable learning experiences. Science instruction should be as thrilling an experience for a student as watching the colors change in a chemical reaction or observing the formation of silver crystals on a copper wire in a solution of silver nitrate. Science is not just for those who have traditionally succeeded in the subject, and it is not just for those who will choose science-related careers. In a world of rapidly expanding knowledge and technology, all students must gain the skills they will need to understand and function responsibly and successfully in the world. The Core provides skills in a context that enables students to experience the joy of doing science.

## Chemistry Core Curriculum

### Science Benchmark

Matter on Earth and in the universe is made of atoms that have structure, mass, and a common origin. The periodic table is used to organize elements by structure. A relationship exists between the chemical behavior and the structure of atoms. The periodic table reflects this relationship.

The nucleus of an atom is a tiny fraction of the volume of the atom. Each proton or neutron in the nucleus is nearly 2,000 times the mass of an electron. Electrons move around the nucleus.

**STANDARD 1: Students will understand that all matter in the universe has a common origin and is made of atoms, which have structure and can be systematically arranged on the periodic table.**

**Objective 1:** Recognize the origin and distribution of elements in the universe.

- Identify evidence supporting the assumption that matter in the universe has a common origin.
- Recognize that all matter in the universe and on earth is composed of the same elements.
- Identify the distribution of elements in the universe.
- Compare the occurrence of heavier elements on earth and the universe.

**Objective 2:** Relate the structure, behavior, and scale of an atom to the particles that compose it.

- Summarize the major experimental evidence that led to the development of various atomic models, both historical and current.
- Evaluate the limitations of using models to describe atoms.
- Discriminate between the relative size, charge, and position of protons, neutrons, and electrons in the atom.
- Generalize the relationship of proton number to the element's identity.
- Relate the mass and number of atoms to the gram-sized quantities of matter in a mole.

**Objective 3:** Correlate atomic structure and the physical and chemical properties of an element to the position of the element on the periodic table.

- Use the periodic table to correlate the number of protons, neutrons, and electrons in an atom.
- Compare the number of protons and neutrons in isotopes of the same element.
- Identify similarities in chemical behavior of elements within a group.
- Generalize trends in reactivity of elements within a group to trends in other groups.
- Compare the properties of elements (e.g., metal, nonmetallic, metalloid) based on their position in the periodic table.

Science language  
students should use:

atom, element, nucleus, proton, neutron, electron, isotope, metal,  
nonmetal, metalloid, malleable, conductive, periodic table

Science Benchmark

The modern atomic model has been developed using experimental evidence. Atomic theories describe the behavior of atoms as well as energy changes in the atom. Energy changes in an isolated atom occur only in discrete jumps. Change in structure and composition of the nucleus result in the conversion of matter into energy.

**STANDARD 2: Students will understand the relationship between energy changes in the atom specific to the movement of electrons between energy levels in an atom resulting in the emission or absorption of quantum energy. They will also understand that the emission of high-energy particles results from nuclear changes and that matter can be converted to energy during nuclear reactions.**

**Objective 1:** Evaluate quantum energy changes in the atom in terms of the energy contained in light emissions.

- a. Identify the relationship between wavelength and light energy.
- b. Examine evidence from the lab indicating that energy is absorbed or released in discrete units when electrons move from one energy level to another.
- c. Correlate the energy in a photon to the color of light emitted.
- d. After observing spectral emissions in the lab (e.g., flame test, spectrum tubes), identify unknown elements by comparison to known emission spectra.

**Objective 2:** Evaluate how changes in the nucleus of an atom result in the emission of radioactivity.

- a. Recognize that radioactive particles and wavelike radiations are products of the decay of an unstable nucleus.
- b. Interpret graphical data relating half-life and age of a radioactive substance.
- c. Compare the mass, energy, and penetrating power of alpha, beta, and gamma radiation.
- d. Compare the strong nuclear force to the amount of energy released in a nuclear reaction and contrast it to the amount of energy released in a chemical reaction.
- e. After researching, evaluate and report the effects of nuclear radiation on humans or other organisms.

Science language students should use:	quanta, wavelength, radiation, emit, absorb, spectrum, half-life, fission, fusion, energy level, mole
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## Science Benchmark

Atoms form bonds with other atoms by transferring or sharing electrons. The arrangement of electrons in an atom, particularly the valence electrons, determines how an atom can interact with other atoms.

The types of chemical bonds holding them together determine many of the physical properties of compounds. The formation of compounds results in a great diversity of matter from a limited number of elements.

### **STANDARD 3: Students will understand chemical bonding and the relationship of the type of bonding to the chemical and physical properties of substances.**

**Objective 1:** Analyze the relationship between the valence (outermost) electrons of an atom and the type of bond formed between atoms.

- Determine the number of valence electrons in atoms using the periodic table.
- Predict the charge an atom will acquire when it forms an ion by gaining or losing electrons.
- Predict bond types based on the behavior of valence (outermost) electrons.
- Compare covalent, ionic, and metallic bonds with respect to electron behavior and relative bond strengths.

**Objective 2:** Explain that the properties of a compound may be different from those of the elements or compounds from which it is formed.

- Use a chemical formula to represent the names of elements and numbers of atoms in a compound and recognize that the formula is unique to the specific compound.
- Compare the physical properties of a compound to the elements that form it.
- Compare the chemical properties of a compound to the elements that form it.
- Explain that combining elements in different proportions results in the formation of different compounds with different properties.

**Objective 3:** Relate the properties of simple compounds to the type of bonding, shape of molecules, and intermolecular forces.

- Generalize, from investigations, the physical properties (e.g., malleability, conductivity, solubility) of substances with different bond types.
- Given a model, describe the shape and resulting polarity of water, ammonia, and methane molecules.
- Identify how intermolecular forces of hydrogen bonds in water affect a variety of physical, chemical, and biological phenomena (e.g., surface tension, capillary action, boiling point).

Science language students should use:	chemical property, physical property, compound, valence electrons, ionic, covalent, malleability, conductivity, solubility, intermolecular, polarity
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## Science Benchmark

In a chemical reaction new substances are formed as atoms and molecules are rearranged. The concept of atoms explains the conservation of matter; since the number of atoms stays the same in a chemical reaction no matter how they are rearranged, the total mass stays the same. Although energy can be absorbed or released in a chemical reaction, the total amount of energy and matter in it remains constant. Many reactions attain a state of equilibrium. Many ordinary activities, such as baking, involve chemical reactions.

**STANDARD 4: Students will understand that in chemical reactions matter and energy change forms, but the amounts of matter and energy do not change.**

**Objective 1:** Identify evidence of chemical reactions and demonstrate how chemical equations are used to describe them.

- Generalize evidences of chemical reactions.
- Compare the properties of reactants to the properties of products in a chemical reaction.
- Use a chemical equation to describe a simple chemical reaction.
- Recognize that the number of atoms in a chemical reaction does not change.
- Determine the molar proportions of the reactants and products in a balanced chemical reaction.
- Investigate everyday chemical reactions that occur in a student's home (e.g., baking, rusting, bleaching, cleaning).

**Objective 2:** Analyze evidence for the laws of conservation of mass and conservation of energy in chemical reactions.

- Using data from quantitative analysis, identify evidence that supports the conservation of mass in a chemical reaction.
- Use molar relationships in a balanced chemical reaction to predict the mass of product produced in a simple chemical reaction that goes to completion.
- Report evidence of energy transformations in a chemical reaction.
- After observing or measuring, classify evidence of temperature change in a chemical reaction as endothermic or exothermic.
- Using either a constructed or a diagrammed electrochemical cell, describe how electrical energy can be produced in a chemical reaction (e.g., half reaction, electron transfer).
- Using collected data, report the loss or gain of heat energy in a chemical reaction.

Science language  
students should use:

chemical reaction, reactants, products, laws of conservation for mass and energy, electrochemical

Science Benchmark

The rate of chemical reactions of atoms and molecules depends upon how often they encounter one another, which is a function of concentration, temperature, and pressure of the reacting materials. Catalysts can be used to change the rate of chemical reactions. Under proper conditions reactions may attain a state of equilibrium.

**STANDARD 5: Students will understand that many factors influence chemical reactions and some reactions can achieve a state of dynamic equilibrium.**

**Objective 1:** Evaluate factors specific to collisions (e.g., temperature, particle size, concentration, and catalysts) that affect the rate of a chemical reaction.

- a. Design and conduct an investigation of the factors affecting reaction rate and use the findings to generalize the results of other reactions.
- b. Use information from graphs to draw warranted conclusions about reaction rates.
- c. Correlate frequency and energy of collisions to reaction rate.
- d. Identify that catalysts are effective in increasing reaction rates.

**Objective 2:** Recognize that certain reactions do not convert all reactants to products, but achieve a state of dynamic equilibrium that can be changed.

- a. Explain the concept of dynamic equilibrium.
- b. Given an equation, identify the effect of adding either product or reactant to a shift in equilibrium.
- c. Indicate the effect of a temperature change on the equilibrium, using an equation showing a heat term.

Science language students should use:	chemical reaction, matter, law of conservation of mass, law of conservation of energy, temperature, electrochemical cell, entropy, chemical equation, endothermic, exothermic, heat, rate, catalyst, concentration, collision theory, equilibrium, half reaction
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Science Benchmark

Solutions make up many of the ordinary substances encountered in everyday life.

The relative amounts of solutes and solvents determine the concentration and the physical properties of a solution. Two important categories of solutions are acids and bases.

**STANDARD 6: Students will understand the properties that describe solutions in terms of concentration, solutes, solvents, and the behavior of acids and bases.**

**Objective 1:** Describe factors affecting the process of dissolving and evaluate the effects that changes in concentration have on solutions.

- a. Use the terms solute and solvent in describing a solution.
- b. Sketch a solution at the particle level.
- c. Describe the relative amount of solute particles in concentrated and dilute solutions and express concentration in terms of molarity and molality.
- d. Design and conduct an experiment to determine the factors (e.g., agitation, particle size, temperature) affecting the relative rate of dissolution.
- e. Relate the concept of parts per million (PPM) to relevant environmental issues found through research.

**Objective 2:** Summarize the quantitative and qualitative effects of colligative properties on a solution when a solute is added.

- a. Identify the colligative properties of a solution.
- b. Measure change in boiling and/or freezing point of a solvent when a solute is added.
- c. Describe how colligative properties affect the behavior of solutions in everyday applications (e.g., road salt, cold packs, antifreeze).

**Objective 3:** Differentiate between acids and bases in terms of hydrogen ion concentration.

- a. Relate hydrogen ion concentration to pH values and to the terms acidic, basic or neutral.
- b. Using an indicator, measure the pH of common household solutions and standard laboratory solutions, and identify them as acids or bases.
- c. Determine the concentration of an acid or a base using a simple acid-base titration.
- d. Research and report on the uses of acids and bases in industry, agriculture, medicine, mining, manufacturing, or construction.
- e. Evaluate mechanisms by which pollutants modify the pH of various environments (e.g., aquatic, atmospheric, soil).

Science language students should use:	solution, solute, solvent, concentration, molarity, percent concentration, colligative property, boiling point, freezing point, acid, base, pH, indicator, titration, hydrogen ion, neutralization, parts per million, concentrated, dilute, dissolve
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## Physics Core Curriculum

The Physics Core Curriculum has two primary goals: (1) students will value and use science as a process of obtaining knowledge based on observable evidence, and (2) students' curiosity will be sustained as they develop and refine the abilities associated with scientific inquiry.

### **Theme**

The Physics Core has three major concepts for the focus of instruction: (1) motion of objects, (2) forces acting on objects, and (3) energy.

### **Inquiry**

Physics students should design and perform experiments, and value inquiry as the fundamental scientific process. They should be encouraged to maintain an open and questioning mind, to pose their own questions about objects, events, processes, and results. They should have the opportunity to plan and conduct their own experiments, and come to their own conclusions as they read, observe, compare, describe, infer, and draw conclusions. The results of their experiments need to be compared for reasonableness to multiple sources of information. They should be encouraged to use reasoning as they apply physics concepts to their lives.

### **Scope**

Not all possible physics topics are specified in the Core. Teachers may enhance their individual classes as they see opportunities to include more topics or more depth. The Physics Core is intended for teachers to help students understand basic physics concepts, develop scientific habits, and experience the process of scientific investigations. Good instruction requires hands-on investigations in which student inquiry is an important goal. Teachers should provide opportunities for **all** students to experience many things. Laboratory investigations should be frequent and meaningful components of physics instruction. Teachers should help students plan and conduct experiments in which they:

- ◆ Identify a problem.
- ◆ Formulate a research question and hypothesis.
- ◆ Identify variables and describe relationships between them.
- ◆ Plan procedures to control independent variables.
- ◆ Collect data on the dependent variable(s).
- ◆ Select the appropriate format (e.g., graph, chart, diagram) to summarize data obtained.
- ◆ Analyze data, check for accuracy, and construct reasonable conclusions.
- ◆ Prepare written and oral reports of investigations.

Students should enjoy science as a process of discovering and understanding the physical world.

## **Relevance**

Physics Core concepts should be integrated with concepts and skills from other curriculum areas. Reading, writing, and mathematics skills should be emphasized as integral to the instruction of science. Personal relevance of science in students' lives is an important part of helping students to value science and should be emphasized at this grade level. Developing students' writing skills in science should be an important part of science instruction in physics. Students should regularly write descriptions of their observations and experiments. Specific science literacy state standards can be found in the *Utah Core State Standards for English, Language Arts, & Literacy in History/Social Studies, Science and Technical Subjects for grades 6-12*.

Providing opportunities for students to gain insights into science related careers adds to the relevance of science learning. Physics provides students with an opportunity to investigate careers in physics, astronomy, engineering, aerospace, and energy.

## **Character**

Value for honesty, integrity, self-discipline, respect, responsibility, punctuality, dependability, courtesy, cooperation, consideration, and teamwork should be emphasized as an integral part of science learning. These relate to the care of living things, safety and concern for self and others, and environmental stewardship. Honesty in all aspects of research, experimentation, data collection, and reporting is an essential component of science.

## **The Use of “i.e.” versus “e.g.” in the Core**

“i.e.” comes from the Latin *id est* and means “in other words” or “this and only this”. Used in the Utah Core Science Curricula, i.e. is interpreted as a learning expectation of all students. The exemplars following an i.e. should be clearly and unambiguously taught in every classroom. In the CRTs, exemplars included in an i.e. statement are assessed as expected knowledge or skills.

“e.g.” comes from the Latin *exempli gratia* and means “including” or “for example”. Used in the Utah Core Science Curricula, e.g. is interpreted as a few possible examples of a larger context or concept. The exemplars following an e.g. are not required, but serve as examples for teaching the specific indicator. Several equally valid exemplars of the same concept may also be taught. In the CRTs, exemplars included as part of an e.g. may serve as the seeds of a good item, but clarifying contextual information will be provided in the item.

## **Resources for Instruction**

This Core was designed using the American Association for the Advancement of Science's *Project 2061: Benchmarks For Science Literacy* and the National Academy of Science's *National Science Education Standards* as guides to determine appropriate content and skills.

The Physics Core has many online resources designed to help with classroom instruction. The Utah Science Home Page at <http://schools.utah.gov/CURR/science/default.aspx> is an ongoing report of resources available and aligned to the Physics Core Curriculum.

## **Safety Precautions**

The hands-on nature of science learning increases the need for teachers to use appropriate precautions in the classroom and field. It is important that all students understand the rules for a safe classroom.

## **The Most Important Goal**

Science instruction should cultivate and build on students' curiosity and sense of wonder. Effective science instruction engages students in enjoyable learning experiences. Science

instruction should be as thrilling an experience for a student as designing, building and testing catapults, bridges and rockets. Science is not just for those who have traditionally succeeded in the subject, and it is not just for those who will choose science-related careers. In a world of rapidly expanding knowledge and technology, all students must gain the skills they will need to understand and function responsibly and successfully in the world. The Core provides skills in a context that enables students to experience the joy of doing science.

# Physics Core Curriculum

## Science Benchmark

The motion of an object can be described by measurements of its position at different times. Velocity is a measure of the rate of change of position of an object. Acceleration is a measure of the rate of change of velocity of an object. This change in velocity may be a change in speed and/or direction. Motion is defined relative to the frame of reference from which it is observed. An object's state of motion will remain constant unless unbalanced forces act upon the object. This is Newton's first law of motion.

### **STANDARD 1: Students will understand how to measure, calculate, and describe the motion of an object in terms of position, time, velocity, and acceleration.**

**Objective 1:** Describe the motion of an object in terms of position, time, and velocity.

- Calculate the average velocity of a moving object using data obtained from measurements of position of the object at two or more times.
- Distinguish between distance and displacement.
- Distinguish between speed and velocity.
- Determine and compare the average and instantaneous velocity of an object from data showing its position at given times.
- Collect, graph, and interpret data for position vs. time to describe the motion of an object and compare this motion to the motion of another object.

**Objective 2:** Analyze the motion of an object in terms of velocity, time, and acceleration.

- Determine the average acceleration of an object from data showing velocity at given times.
- Describe the velocity of an object when its acceleration is zero.
- Collect, graph, and interpret data for velocity vs. time to describe the motion of an object.
- Describe the acceleration of an object moving in a circular path at constant speed (e.g., constant speed, but changing direction).
- Analyze the velocity and acceleration of an object over time.

**Objective 3:** Relate the motion of objects to a frame of reference.

- Compare the motion of an object relative to two frames of reference.
- Predict the motion of an object relative to a different frame of reference (e.g., an object dropped from a moving vehicle observed from the vehicle and by a person standing on the sidewalk).
- Describe how selecting a specific frame of reference can simplify the description of the motion of an object.

**Objective 4:** Use Newton's first law to explain the motion of an object.

- Describe the motion of a moving object on which balanced forces are acting.
- Describe the motion of a stationary object on which balanced forces are acting.
- Describe the balanced forces acting on a moving object commonly encountered (e.g., forces acting on an automobile moving at constant velocity, forces that maintain a body in an upright position while walking).

Science language students should use:

position, time, speed, velocity, acceleration, distance, displacement, rate, instantaneous velocity, average velocity, frame of reference, balanced forces

## Science Benchmark

Objects in the universe interact with one another by way of forces. Changes in the motion of an object are proportional to the sum of the forces, and inversely proportional to the mass. If one object exerts a force on a second object, the second object always exerts an equal and opposite force on the first object. Whenever a force is applied to an object there is an equal and opposite reaction force.

Friction, tension, compression, spring, gravitational, and normal forces are all common observable forces. The net force on an object is the vector sum of all the forces acting upon the object.

### **STANDARD 2: Students will understand the relation between force, mass, and acceleration.**

**Objective 1:** Analyze forces acting on an object.

- a. Observe and describe forces encountered in everyday life (e.g., braking of an automobile - friction, falling rain drops - gravity, directional compass - magnetic, bathroom scale - elastic or spring).
- b. Use vector diagrams to represent the forces acting on an object.
- c. Measure the forces on an object using appropriate tools.
- d. Calculate the net force acting on an object.

**Objective 2:** Using Newton's second law, relate the force, mass, and acceleration of an object.

- a. Determine the relationship between the net force on an object and the object's acceleration.
- b. Relate the effect of an object's mass to its acceleration when an unbalanced force is applied.
- c. Determine the relationship between force, mass, and acceleration from experimental data and compare the results to Newton's second law.
- d. Predict the combined effect of multiple forces (e.g., friction, gravity, and normal forces) on an object's motion.

**Objective 3:** Explain that forces act in pairs as described by Newton's third law.

- a. Identify pairs of forces (e.g., action-reaction, equal and opposite) acting between two objects (e.g., two electric charges, a book and the table it rests upon, a person and a rope being pulled).
- b. Determine the magnitude and direction of the acting force when magnitude and direction of the reacting force is known.
- c. Provide examples of practical applications of Newton's third law (e.g., forces on a retaining wall, rockets, walking).
- d. Relate the historical development of Newton's laws of motion to our current understanding of the nature of science (e.g., based upon previous knowledge, empirical evidence, replicable observations, development of scientific law).

Science language students should use:	force, normal force, vector, vector diagram, friction, gravity, net force
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Science Benchmark

Any two objects in the universe with mass exert equal and opposite gravitational forces on one another. The electromagnetic force is manifested as an electric force, a magnetic force, or a combination. Any two objects in the universe with a net electric charge exert equal and opposite electric forces on one another. While gravitational forces are always attractive, electromagnetic forces can be either attractive or repulsive.

**STANDARD 3: Students will understand the factors determining the strength of gravitational and electric forces.**

**Objective 1:** Relate the strength of the gravitational force to the distance between two objects and the mass of the objects (e.g., Newton’s law of universal gravitation).

- a. Investigate how mass affects the gravitational force (e.g., spring scale, balance, or other method of finding a relationship between mass and the gravitational force).
- b. Distinguish between mass and weight.
- c. Describe how distance between objects affects the gravitational force (e.g., effect of gravitational forces of the moon and sun on objects on Earth).
- d. Explain how evidence and inference are used to describe fundamental forces in nature, such as the gravitational force.
- e. Research the importance of gravitational forces in the space program.

**Objective 2:** Describe the factors that affect the electric force (e.g., Coulomb’s law).

- a. Relate the types of charge to their effect on electric force (e.g., like charges repel, unlike charges attract).
- b. Describe how the amount of charge affects the electric force.
- c. Investigate the relationship of distance between charged objects and the strength of the electric force.
- d. Research and report on electric forces in everyday applications found in both nature and technology (e.g., lightning, living organisms, batteries, copy machine, electrostatic precipitators).

Science language students should use:	electric force, electric charge, gravitational force, mass, weight, vector, vector diagram
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## Science Benchmark

The total energy of the universe is constant; however, the total amount of energy available for useful transformation is almost always decreasing. Energy can be converted from one form to another and move from one system to another. Transformation of energy usually produces heat that spreads to cooler places by radiation, convection, or conduction. Energy can be classified as potential or kinetic energy. Potential energy is stored energy and includes chemical, gravitational, electrostatic, elastic, and nuclear. Kinetic energy is the energy of motion.

Moving electric charges produce magnetic forces and moving magnets produce electric forces. The interplay of electric and magnetic forces is the basis for electric motors, generators, and many other modern technologies, including the production of electromagnetic waves. Modern electric generators produce electricity by converting mechanical energy into electrical energy.

### **STANDARD 4: Students will understand transfer and conservation of energy.**

**Objective 1:** Determine kinetic and potential energy in a system.

- a. Identify various types of potential energy (e.g., gravitational, elastic, chemical, electrostatic, nuclear).
- b. Calculate the kinetic energy of an object given the velocity and mass of the object.
- c. Describe the types of energy contributing to the total energy of a given system.

**Objective 2:** Describe conservation of energy in terms of systems.

- a. Describe a closed system in terms of its total energy.
- b. Relate the transformations between kinetic and potential energy in a system (e.g., moving magnet induces electricity in a coil of wire, roller coaster, internal combustion engine).
- c. Gather data and calculate the gravitational potential energy and the kinetic energy of an object (e.g., pendulum, water flowing downhill, ball dropped from a height) and relate this to the conservation of energy of a system.
- d. Evaluate social, economic, and environmental issues related to the production and transmission of electrical energy.

**Objective 3:** Describe common energy transformations and the effect on availability of energy.

- a. Describe the loss of useful energy in energy transformations.
- b. Investigate the transfer of heat energy by conduction, convection, and radiation.
- c. Describe the transformation of mechanical energy into electrical energy and the transmission of electrical energy.
- d. Research and report on the transformation of energy in electrical generation plants (e.g., chemical to heat to electricity, nuclear to heat to mechanical to electrical, gravitational to kinetic to mechanical to electrical), and include energy losses during each transformation.

Science language students should use:	potential energy, kinetic energy, energy, gravitational potential energy, law of conservation of energy, elastic potential energy
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Science Benchmark

Sound and light transfer energy from one location to another as waves. Characteristics of waves include wavelength, amplitude, and frequency. Waves can combine with one another, bend around corners, reflect off surfaces, be absorbed by materials they enter, and change direction when entering a new material. All these effects vary with wavelength. Observable waves include mechanical and electromagnetic waves. Mechanical waves transport energy through a medium. Electromagnetic radiation is differentiated by wavelength or frequency, and includes radio waves, microwaves, infrared, visible light, ultraviolet radiation, x-rays, and gamma rays. These wavelengths vary from radio waves (the longest) to gamma rays (the shortest). In empty space all electromagnetic waves move at the same speed, the “speed of light.”

**STANDARD V: Students will understand the properties and applications of waves.**

**Objective 1:** Demonstrate an understanding of mechanical waves in terms of general wave properties.

- a. Differentiate between period, frequency, wavelength, and amplitude of waves.
- b. Investigate and compare reflection, refraction, and diffraction of waves.
- c. Provide examples of waves commonly observed in nature and/or used in technological applications.
- d. Identify the relationship between the speed, wavelength, and frequency of a wave.
- e. Explain the observed change in frequency of a mechanical wave coming from a moving object as it approaches and moves away (e.g., Doppler effect).
- f. Explain the transfer of energy through a medium by mechanical waves.

**Objective 2:** Describe the nature of electromagnetic radiation and visible light.

- a. Describe the relationship of energy to wavelength or frequency for electromagnetic radiation.
- b. Distinguish between the different parts of the electromagnetic spectrum (e.g., radio waves and x-rays or visible light and microwaves).
- c. Explain that the different parts of the electromagnetic spectrum all travel through empty space and at the same speed.
- d. Explain the observed change in frequency of an electromagnetic wave coming from a moving object as it approaches and moves away (e.g., Doppler effect, red/blue shift).
- e. Provide examples of the use of electromagnetic radiation in everyday life (e.g., communications, lasers, microwaves, cellular phones, satellite dishes, visible light).

Science language students should use:	wave, mechanical wave, electromagnetic wave, electromagnetic spectrum, wavelength, frequency, amplitude, period, reflection, refraction, diffraction, Doppler effect, medium, radio wave, microwave, infrared, visible light, ultraviolet, x-ray, gamma ray, conduction, convection, radiation
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