Utah Science Core Curriculum
Physics

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 Were 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. The vignettes listed on the Utah Science Home Page at http://www.usoe.k12.ut.us/curr/science for each of the Core standards provide examples, based on actual practice, that demonstrate that excellent teaching of the Science Core is possible.

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://www.usoe.k12.ut.us/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 of and interest in science.

Intended Learning Outcomes for Physics

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

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. Lab journals are an effective way to emphasize the importance of writing in science.

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. Resources related to careers in science may be found at the Utah Science Home Page at http://www.usoe.k12.ut.us/curr/science .

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 Physics Core has many online resources designed to help with classroom instruction. The Utah Science Home Page at http://www.usoe.k12.ut.us/curr/science 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 I: 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.
a. Calculate the average velocity of a moving object using data obtained from measurements of position of the object at two or more times.
b. Distinguish between distance and displacement.
c. Distinguish between speed and velocity.
d. Determine and compare the average and instantaneous velocity of an object from data showing its position at given times.
e. 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.
a. Determine the average acceleration of an object from data showing velocity at given times.
b. Describe the velocity of an object when its acceleration is zero.
c. Collect, graph, and interpret data for velocity vs. time to describe the motion of an object.
d. Describe the acceleration of an object moving in a circular path at constant speed (i.e., constant speed, but changing direction).
e. Analyze the velocity and acceleration of an object over time.

Objective 3: Relate the motion of objects to a frame of reference.
a. Compare the motion of an object relative to two frames of reference.
b. 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).
c. 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.
a. Describe the motion of a moving object on which balanced forces are acting.
b. Describe the motion of a stationary object on which balanced forces are acting.
c. 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.

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.

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 II: 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).

STANDARD III: 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 (i.e., 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 (i.e., Coulomb's law).

a. Relate the types of charge to their effect on electric force (i.e., 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:	force, electric force, electric charge, friction, gravitational force, mass, net force, normal force, weight, vector, vector diagram

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.

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 IV: 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 (i.e., 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.

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 (i.e., 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 (i.e., 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:	energy, potential energy, kinetic energy, law of conservation of energy, wave, mechanical wave, electromagnetic wave, electromagnetic spectrum, wavelength, frequency, amplitude, period, reflection, refraction, diffraction, Doppler effect, elastic potential energy, medium, radio wave, microwave, infrared, visible light, ultraviolet, x-ray, gamma ray, conduction, convection, radiation