Illinois Science Assessment Framework
PSAE Grade 11

State Assessments Beginning

Spring 2006

Illinois State Board of Education

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Introduction to the Illinois Science Assessment Framework
PSAE Grade 11

The Illinois Science Assessment Framework for PSAE Grade 11 is designed to assist educators, test developers, policy makers, and the public by clearly defining those elements of the Illinois Learning Standards that are suitable for state testing. It is not designed to replace a local science curriculum and should not be considered a state science curriculum. The Framework defines the science content that will be assessed in the Prairie State Achievement Examination (PSAE) beginning with the 2005-06 school year.

Assessment Objectives
The Science Assessment Framework provides the specifications for the content of the PSAE for spring of 2006. As the tests are designed to measure the Illinois Learning Standards, using the Science Assessment Framework in curriculum and instructional design will provide valuable guidance to educators and students. The assessment objectives reflect a combination of the ACT Assessment® Science Test and the ISBE-developed Science. They do not represent either the ACT Assessment Science Test or the ISBE-developed Science in isolation.

Content Emphasis and Reports
While the precise content on each year's assessment will vary somewhat from year to year, the relative emphasis on the State Goals and Illinois Learning Standards will not. The proportion of each year's assessment devoted to each of the categories of assessment objectives is clearly specified in the Science Content Category Table on page 7. In addition to an overall PSAE Science score, an ACT Assessment Science Test score, and an overall ISBE-developed Science score, as much information as possible will be reported.

Science Assessment Structure
The science portion of the PSAE is comprised of two components: the ACT Assessment Science Test on Day 1 and ISBE-developed Science on Day 2. Each component contributes 50% to the total PSAE Science scale score.

The expectations for Day 2 of the PSAE include the assessment objectives from grades 4 and 7. For example, one assessment objective for grade 4 states that students are expected to know the differences between living and non-living things. Students are also expected to know these differences at grade 11. In another example, an assessment objective for grade 7 states that students should be able to identify common insects by their features. Likewise, it is expected that students be able to identify those features at grade 11.

Framework Structure
This document employs a general organizational structure designed for ease of use. Each State Goal for science is the main organizer, followed by the Illinois Learning Standards for Science within each of these State Goals. Each assessment objective has a unique identifier with three components.

Example: 13.11.01

13	***11***	***01***
State Goal	***Grade Level***	***Objective Number***

The first component, *"13,"* indicates the numbered State Goal as defined in the Illinois Learning Standards. The second component, *"11,"* indicates the grade level. The third component, *"01,"* indicates that this is the first assessment objective for this State Goal at this grade level.

Cognitive Complexity
Cognitive complexity refers to the level of reasoning called for by an assessment objective. For example, some assessment objectives require simple recall, while others may require more complex levels of reasoning and/or application of knowledge and skills.

The nature of the content is such that the cognitive complexity implied by each assessment objective can vary widely. Descriptions of the various levels are presented in the Science Productive Thinking Scale below.

Science Productive Thinking Scale Table[1]

Level 1 Questions Recall of Conventions (e.g., names, vocabulary, measurement units, etc.)
Level 2 Questions Reproduction of Facts (e.g., empirical facts/relationships, steps in processes, scientific tools, etc.)
Level 3 Questions Reproduction of Theory (e.g., empirical theories/causes or reasons for scientific methods)
Level 4 Questions One-step applications of laws, rules, or knowledge of one-variable experiments
Level 5 Questions Two-step applications of laws, rules, or knowledge of two-variable experiments
Level 6 Questions Creation of scientific theories or new scientific methods, ranging from simple analogies to Galileo's development of systematic scientific methodology

[1] The Science Productive Thinking Scale, including descriptions of each of the six levels, is explained in greater detail in the publication *Illinois Science Productive Thinking Scale* from the Illinois State Board of Education.

Excerpt from *Illinois Learning Standards*[2]

The *Illinois Learning Standards for Science* were developed using the 1985 State Goals for Science, the National Science Education Standards, various other state and national works, and local education standards contributed by team members.

Science is a creative endeavor of the human mind. It offers a special perspective of the natural world in terms of understanding and interaction. The aim of science education is to develop in learners a rich and full understanding of the inquiry process; the key concepts and principles of life sciences, physical science, and earth and space sciences; and issues of science, technology, and society in historical and contemporary contexts. The National Science Education Standards present these understandings and their interactions with the natural world as eight science content standard categories. The *Illinois Learning Standards for Science* integrate these categories into a powerful resource for the design and evaluation of science curricula taught in Illinois schools.

The *Illinois Learning Standards for Science* are organized by goals that inform one another and depend upon one another for meaning. Expectations for learners related to the inquiry process are presented in standards addressing the doing of science and elements of technological design. Unifying concepts connect scientific understanding and process and are embedded in standards spanning life science, physical science, and earth and space science. The importance of this knowledge and its application is conveyed in standards describing the conventions and nature of the scientific enterprise and the interplay among science, technology and society in past, present and future contexts.

APPLICATIONS OF LEARNING
Through Applications of Learning, students demonstrate and deepen their understanding of basic knowledge and skills. These applied learning skills cross academic disciplines and reinforce the important learning of the disciplines. The ability to use these skills will greatly influence students' success in school, in the workplace and in the community.

SOLVING PROBLEMS
Recognize and investigate problems; formulate and propose solutions supported by reason and evidence.
Asking questions and seeking answers are at the heart of scientific inquiry. Following the steps of scientific inquiry, students learn how to gather evidence, review and understand their findings, and compare their solutions with those of others. They learn that there can be differing solutions to the same problem, some more useful than others. In the process, they learn and apply scientific principles. They also learn to be objective in deciding whether their solutions meet specifications and perform as desired.

COMMUNICATING
Express and interpret information and ideas.
Scientists must carefully describe their methods and results to a variety of audiences, including other scientists. This requires precise and complete descriptions and the presentation of conclusions supported by evidence. Young science students develop the powers of observation and description. Older students gain the ability to organize and study data, to determine its meaning, to translate their findings into clear understandable language and to compare their results with those of other investigators.

[2] Illinois State Board of Education (1997). *Illinois Learning Standards*

USING TECHNOLOGY

Use appropriate instruments, electronic equipment, computers and networks to access information, process ideas and communicate results.

Technology is invented and improved by the use of scientific principles. In turn, scientists depend on technology in performing experiments, analyzing data and communicating the results. Science students learn to use a range of technologies: instruments, computer hardware and software, on-line services and equipment, primary source data and images, and communication networks. They learn how technology, in turn, is the result of a scientific design process that includes continual refinements and improvements.

WORKING ON TEAMS

Learn and contribute productively as individuals and as members of groups.

The practical application of science requires both individual and group efforts. Individuals bring unique insight and focus to the work of inquiry and problem solving. Working in groups, scientists pose questions, share hypotheses, divide their experimental efforts, and share data and results. Science students have the opportunity to work both ways—as individuals and as members of teams organized to conduct complex investigations and solve problems.

MAKING CONNECTIONS

Recognize and apply connections of important information and ideas within and among learning areas.

Science has many disciplines, all interrelated. Understanding the functioning of living things depends on knowing chemistry; understanding chemistry depends on knowing physics. In the same way, science itself is highly dependent on mathematics—and it also relates strongly to medicine, geography, physical development and health, social trends and issues, and many other topics. Science, at its best, provides knowledge and skills that improve the understanding of virtually all subjects.

STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

Why This Goal Is Important: The inquiry process prepares learners to engage in science and apply methods of technological design. This understanding will enable students to pose questions, use models to enhance understanding, make predictions, gather and work with data, use appropriate measurement methods, analyze results, draw conclusions based on evidence, communicate their methods and results, and think about the implications of scientific research and technological problem solving.

STANDARD 11A

Know and apply the concepts, principles and processes of scientific inquiry.

STANDARD 11B

Know and apply the concepts, principles and processes of technological design.

STATE GOAL 12: Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences.

Why This Goal Is Important: This goal is comprised of key concepts and principles in the life, physical and earth/space sciences that have considerable explanatory and predictive power for scientists and non-scientists alike. These ideas have been thoroughly studied and have stood the test of time. Knowing and being able to apply these concepts, principles and processes help students understand what they observe in nature and through scientific experimentation. A working knowledge of these concepts and principles allows students to relate new subject matter to material previously learned and to create deeper and more meaningful levels of understanding.

STANDARD 12A
Know and apply concepts that explain how living things function, adapt and change.

STANDARD 12B
Know and apply concepts that describe how living things interact with each other and with their environment.

STANDARD 12C
Know and apply concepts that describe properties of matter and energy and the interactions between them.

STANDARD 12D
Know and apply concepts that describe force and motion and the principles that explain them.

STANDARD 12E
Know and apply concepts that describe the features and processes of the Earth and its resources.

STANDARD 12F
Know and apply concepts that explain the composition and structure of the universe and Earth's place in it.

STATE GOAL 13: Understand the relationships among science, technology and society in historical and contemporary contexts.

Why This Goal Is Important:
Understanding the nature and practices of science such as ensuring the validity and replicability of results, building upon the work of others and recognizing risks involved in experimentation gives learners a useful sense of the scientific enterprise. In addition, the relationships among science, technology and society give humans the ability to change and improve their surroundings. Learners who understand this relationship will be able to appreciate the efforts and effects of scientific discovery and applications of technology on their own lives and on the society in which we live.

STANDARD 13A
Know and apply the accepted practices of science.

STANDARD 13B
Know and apply concepts that describe the interaction between science, technology and society.

Science Content Category Table
PSAE Grade 11

Note: The Content Category Table was revised in November 2006

	Day 1 ACT Science Test	Day 2 ISBE-Developed Science
State Goal 11	**100%**	**5%**
Standard 11A – Scientific Inquiry	100%	0%
Standard 11B – Technological Design	0%	5%
State Goal 12	**0%***	**75%**
Standard 12A – Living Things[3]	0%*	15%
Standard 12B – Environment and Interaction of Living Things[4]	0%*	10%
Standard 12C – Matter and Energy[5]	0%*	15%
Standard 12D – Force and Motion	0%*	10%
Standard 12E – Earth Science[6]	0%*	15%
Standard 12F – Astronomy	0%*	10%
State Goal 13	**0%**	**20%**
Standard 13A – Safety and Practices of Science	0%	10%
Standard 13B – Science, Technology, and Society[7]	0%	10%
Total	**100%**	**100%**

Note: The science portion of the PSAE is a combination of the ACT Assessment Science component and the ISBE-developed Science component. Each component contributes 50% to the total PSAE Science scale score.

Note Added on 3/18/08: A new scoring methodology was announced that affects only reading and mathematics. For more information, please see http://www.isbe.net/assessment/listserv/2008/mar14.htm.

*The ACT Science Test contains passages about representative topics in the disciplines of biology, chemistry, physics, and the Earth/space sciences. Moreover, the questions on the test emphasize scientific reasoning in these disciplines, and some questions require examinees to apply content knowledge acquired in the study of these disciplines. However, the test does not systematically sample from the full content domain described by the Illinois Science Assessment Framework. That is, each form of the ACT Science Test assesses some content knowledge described by the Framework, but not in a systematic way that would allow percentages to be provided by science standard.

[3] Includes the following topics: Classification, Cell Biology, Genetics and Reproduction, Change Over Time
[4] Includes the following topic: Ecology and Adaptation
[5] Includes the following topics: Properties of Matter, The Atom, Acids and Bases, Energy, Light and Sound
[6] Includes the following topics: The Earth's Structure, The Earth's Dynamic Processes, The Atmosphere, Water
[7] Includes the following topic: Measurement

Grade 11

STANDARD 11A – SCIENTIFIC INQUIRY

11.11.01 Understand and follow procedures relating to scientific investigations, including understanding the design and procedures used to test a hypothesis, organizing and analyzing data accurately and precisely, producing and interpreting data tables and graphs, performing appropriate calculations, applying basic statistical methods to the data, identifying appropriate conclusions, making predictions, and evaluating competing models.

11.11.02 Distinguish among the following: observing, drawing a conclusion based on observation, forming a hypothesis, conducting an experiment, organizing data, comparing data.

11.11.03 Identify possible sources of error in an experiment.

11.11.04 Distinguish and define the following components of typical experiments: constants, variables, experimental group, control group (or control setup).

STANDARD 11B – TECHNOLOGICAL DESIGN

11.11.05 Identify a technological design problem inherent in a given product.

11.11.06 Out of different lists of criteria, select the list of criteria outlining a successful design solution to a given problem.

11.11.07 Given test results on different models, choose the model which best solves the design problem.

11.11.08 Given a description of a test to be performed on a model, select from a list of options what are the possible sources of error in conducting the test.

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STANDARD 12A – LIVING THINGS

Classification

12.11.01 Identify the major categories (taxa) of biological classification: kingdom, phylum, class, order, family, genus, and species.

12.11.02 Understand the kingdoms used by taxonomists: a 5-kingdom system; monera, protista, fungi, plantae, and animalia and a 6-kingdom system; eubacteria, archaebacteria, protista, fungi, plantae, and animalia. Students should be able to identify organisms within the systems. Understand how to read a cladogram and a dichotomous key.

12.11.03 Identify the following basic animal types by their common characteristics: sponges, cnidarians, flatworms and roundworms, mollusks, arthropods, echinoderms, invertebrate chordates, and vertebrates.

Cell Biology

12.11.04 Identify the similarities and differences between plant and animal cells (i.e., know the various fundamental organelles of plant and animal cells and be able to distinguish these organelles in diagrams).

12.11.05 Understand how the semi-permeable membranes regulate the flow of substances in and out of the cell body.

12.11.06 Understand the role of the endoplasmic reticulum and Golgi apparatus in the secretion of proteins.

12.11.07 Understand that chloroplasts in plant cells capture useable energy from sunlight and store it for future use by synthesizing sugar out of carbon dioxide and water.

12.11.08 Understand the role of mitochondria in making stored chemical-bond energy available to cells by completing the breakdown of glucose to carbon dioxide and water.

12.11.09 Understand that the chief energy-storing compound used by organisms is ATP (adenosine triphosphate).

12.11.10 Understand that enzymes are proteins that catalyze biochemical reactions and that the activity of enzymes depends on the temperature, ionic conditions, and the pH of the surroundings.

12.11.11 Understand how prokaryotic cells, eukaryotic cells (whether of animals or plants and whether unicellular or multicellular), and viruses differ in complexity and structure. In particular: 1. Prokaryotes are organisms whose cells lack nuclei. They are usually small and unicellular. 2. Eukaryotes are organisms whose cells have nuclei and membrane bound organelles. 3. A virus is a non-cellular particle usually made up of genetic material and protein that can invade living cells. Viruses are also much smaller than any unicellular organism (such as a bacterium) and cannot be seen with light microscopes but only with electron microscopes.

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STANDARD 12A – LIVING THINGS (Continued)

Genetics and Reproduction

12.11.12 Understand Mendel's law of segregation and also that genes do not always separate as hypothesized by Mendel's law of segregation. Understand that if genes are located close to each other on the same chromosome, then they are linked and may undergo independent assortment.

12.11.13 Identify and be able to apply the following concepts: trait, alleles, dominant allele, recessive allele, gametes, genotype, homozygous, heterozygous, chromosome, meiosis, and mitosis.

12.11.14 Answer questions about given Punnett squares.

12.11.15 Understand that meiosis is an early step in sexual reproduction in which the pairs of chromosomes separate and segregate randomly during cell division to produce gametes containing one chromosome of each pair. Understand that only certain cells in a multicellular organism undergo meiosis.

12.11.16 Understand how random chromosome segregation explains the probability that a particular allele will be in a gamete.

12.11.17 Know why about half of an individual's DNA sequence comes from each parent. Understand that most of the cells in a human contain pairs of 22 different autosomes and one pair of sex chromosomes.

12.11.18 Understand that in humans there is a pair of chromosomes that determines sex: a female usually contains two X chromosomes and a male usually contains one X and one Y chromosome.

12.11.19 Understand how to predict possible combinations of alleles in a zygote from the genetic makeup of the parents for simple dominant/recessive traits.

12.11.20 Understand that a multicellular organism develops from a single zygote, and its phenotype (i.e. its outward appearance) depends on its genotype (i.e. its genetic makeup), which is established at fertilization.

12.11.21 Understand that, in all living things, DNA (deoxyribonucleic acid) carries the instructions for specifying the characteristics of each organism. Understand that DNA is a large polymer formed from four subunits: A, G, C, and T (adenine, guanine, cytosine, thymine, a 5-carbon sugar and a phosphate). The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular letters) and replicated (by a templating mechanism). Know that each DNA molecule in a cell is a single chromosome.

12.11.22 Understand that a gene is a set of instructions in the DNA sequence of each organism that specifies the sequence of amino acids in polypeptides characteristic of that organism.

12.11.23 Understand the general steps by which ribosomes synthesize proteins, using information from mRNA and from amino acids delivered by tRNA.

12.11.24 Understand that specialization of cells in multicellular organisms is usually due to different patterns of gene expression rather than to differences of the genes themselves.

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STANDARD 12A – LIVING THINGS (Continued)

Change Over Time

12.11.25 Understand that natural selection acts on the phenotype, not the genotype, of an organism.

12.11.26 Understand that alleles that are lethal in a homozygous individual may be carried in a heterozygote and thus maintained in a gene pool.

12.11.27 Understand that variation within a species increases the likelihood that at least some members of a species will survive and reproduce under changed environmental conditions.

12.11.28 Understand that reproductive or geographic isolation can lead to speciation.

12.11.29 Understand that the millions of different species of plants, animals, and microorganisms that live on Earth today are related to each other by descent from common ancestors and that biological classifications are based on how organisms are related.

12.11.30 Understand how to analyze fossil evidence with regard to mass extinction, episodic speciation, and biological diversity.

STANDARD 12B – ENVIRONMENT AND INTERACTION OF LIVING THINGS

Ecology and Adaptation

12.11.31 Understand the causes of ecosystem disruptions: changes in climate, human activity, introduction of a nonnative species, changes in population size, sudden natural disasters.

12.11.32 Know that fluctuations in population size are determined by the relative rates of birth, immigration, emigration, and death.

12.11.33 Know that concentrations of nonbiodegradable pollutants (e.g., pesticides) increase as we go up in a particular food chain (i.e., that the further we go in the direction of consumers whose food is tainted with pesticide, the more concentrated the levels of the pesticide). Understand that this process is called biological magnification.

12.11.34 Understand how agricultural run-off and pollution entering groundwater and surface water can affect drinking water and local wildlife.

12.11.35 Understand that a vital part of an ecosystem is the stability of its producers and decomposers.

12.11.36 Understand the effects upon the population of a species caused by various ecological factors, particularly (a) the presence of another species with competitive feeding habits, (b) the presence (or absence) of and number of predators, (c) the abundance or scarcity of food sources.

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STANDARD 12C – MATTER AND ENERGY

Properties of Matter

12.11.37 Identify the most familiar elements by name and some of their most familiar properties. Identify the chemical symbols for familiar elements.

12.11.38 Know that atoms are made of sub-atomic particles (protons, neutrons, electrons) which have positive, neutral, or negative charges. Understand that the periodic table displays the elements in increasing atomic number and shows how periodicity of the physical and chemical properties of the elements relates to atomic structure.

12.11.39 Understand how to relate the position of an element in the periodic table to its chemical properties.

12.11.40 Understand how to use the periodic table to identify the families of elements (and their properties) known as alkali metals, alkaline Earth metals, halogens, and noble gases.

12.11.41 Know that there is a kind of periodicity in the physical properties of chemical elements, that the periodic table arranges them accordingly, and that this way of ordering them corresponds to the order in their atomic structures. Understand that the major groups of chemical elements are: (1) alkali metals, (2) alkaline Earth metals, (3) transition metals, (4) nonmetals (boron family, carbon family, nitrogen family, oxygen family, halogen family, noble gases), (5) metalloids, and (6) rare Earth elements. Know why hydrogen is not in any of these groups.

12.11.42 Know that there are two major different kinds of bonds (ionic and covalent). Know the distinction between a compound and a mixture.

12.11.43 Understand how to use the periodic table to identify the trends in relative sizes of ions and atoms.

12.11.44 Understand how to use the periodic table to determine the number of electrons available for bonding.

12.11.45 Understand that the nucleus of the atom is much smaller than the whole atom yet contains most of its mass. Understand isotopes.

12.11.46 Understand that the transuranium elements were not discovered in nature but synthesized through the use of nuclear accelerators.

12.11.47 Understand the different states of matter: solid, liquid, gas, plasma. Define freezing, melting, boiling, condensing, and sublimation.

12.11.48 Understand that the temperature of water (or any substance) is constant during phase changes, even when heat is being added or removed.

12.11.49 Understand that the kinetic molecular theory explains the properties of gases by the random motion of molecules in them. For example, the collisions of these particles with a surface create an observable pressure on that surface, and their motion explains the diffusion of gases.

12.11.50 Understand how to apply the gas laws to relations between pressure, temperature, and volume of any amount of an ideal gas. Understand Boyle's Law and Charles' Law and how to logically solve problems.

12.11.51 Understand the values of standard temperature and pressure (STP): 0° Celsius and 1 atm.

12.11.52 Understand how to convert between Celsius and Kelvin temperature scales. Understand that there is no temperature lower than 0 Kelvin, or absolute zero.

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STANDARD 12C – MATTER AND ENERGY (Continued)

The Atom

12.11.53 Understand that in chemical reactions, atoms combine into molecules by means of bonds (e.g., by sharing electrons to form covalent or metallic bonds or by exchanging electrons to form ionic bonds).

12.11.54 Know that ions are atoms or groups of atoms that have a positive or negative charge and that polyatomic ions are a group of covalently bonded atoms that act like a single atom when combining with other atoms. Understand that metals tend to form positive ions, and nonmetals tend to form negative ions.

12.11.55 Understand that ionic solids like NaCl (sodium chloride, ordinary table salt) are formed from a three-dimensional repeating pattern of alternating positive and negative ions, held together by electrostatic forces (ionic bonds).

12.11.56 Understand that the conservation of atoms in a chemical reaction, as summarized in a balanced chemical equation, leads to the ability to calculate theoretical masses of reactants and products.

12.11.57 Understand how to read, interpret, and balance chemical equations.

12.11.58 Understand that the chemical quantity called ~~"o~~ne mole" is set by calling the number of atoms in exactly 12 grams of carbon-12 atoms one mole. This number turns out to be 6.02×10^{23}, also known as Avogadro's Number

12.11.59 Understand that energy is exchanged or transformed in all chemical reactions and physical changes of matter. Understand that chemical processes can either release (exothermic) or absorb (endothermic) thermal energy. Understand that energy is released when a material condenses or freezes and is absorbed when a material evaporates, melts, or sublimes.

Acids and Bases

12.11.60 Understand that most acids, bases, and salts, when dissolved in water, conduct electric current and form ions in water solutions. Understand the observable properties of acids, bases, and salt solutions.

12.11.61 Understand that among other definitions of acids and bases, acids are hydrogen-ion-donating and bases are hydrogen-ion-accepting substances.

12.11.62 Use the pH scale to characterize acidic and basic solutions. Understand the definition of pH as the negative logarithm of the hydronium ion concentration, and understand what the log scale means.

12.11.63 Distinguish between chemical compounds and solutions and mixtures. Differentiate between solute and solvent. Understand the concentration of a solute in terms of molarity, parts per million, and percent composition.

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STANDARD 12C – MATTER AND ENERGY (Continued)

Energy

12.11.64 Understand that energy, defined somewhat circularly, is ~~"t~~he ability to change matter," or ~~"t~~he ability to do work." Understand that energy is defined by the way it is measured or quantified. Understand the difference between potential and kinetic energy.

12.11.65 Understand that a magnetic field is generated around an electrical current and that the motion of a conducting wire through a magnetic field generates a current through it. Understand that in some substances, such as metals, electrons flow easily, whereas in insulating materials such as glass they can hardly flow at all. Semiconducting materials have intermediate behavior. At very low temperatures, some materials offer no resistance to the flow of electrons and become superconductors.

12.11.66 Understand that an electrically neutral object has particles within it that are charged, but their charges balance each other out.

12.11.67 Know the first two laws of thermodynamics: (1) Energy is conserved (neither created nor destroyed) and (2) Heat flows naturally from a hot object to a cold object; heat will not flow spontaneously from a cold object to a hot object. Understand that another statement of the Second Law is that no device is possible whose sole effect is to transform a given amount of heat completely into work.

12.11.68 Recount the concept of entropy and know that entropy in the universe considered as a whole always increases.

Light and Sound

12.11.69 Indicate that the speed of light differs in some material from its speed in a vacuum is given by the index of refraction for that material, n, where n is the ratio of the speed of light in a vacuum to the speed of light in the material. Also know that light follows the path of least time through various materials and that this is not the same as the shortest distance.

12.11.70 Understand the reflection, refraction, diffraction, interference, and frame of reference properties of waves.

12.11.71 Understand that sound causes molecules of a medium to vibrate back and forth. This series of compressions and rarefactions produces waves.

12.11.72 Understand how sound travels through different mediums.

12.11.73 Understand amplitude, frequency, wavelength, intensity, and quality. Know that intensity is measured in decibels.

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STANDARD 12D – FORCE AND MOTION

12.11.74 Understand that the magnitude of a force *F* is defined as *F = ma* (Force equals Mass times Acceleration). Know how to perform such calculations. Understand that whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object. Understand that when two objects exert forces on each other, momentum is conserved.

12.11.75 Understand that objects change their velocity only when a net force is applied (the law of inertia). Understand that mass can be defined in terms of inertia and in terms of gravity. Students will be able to distinguish how inertial and gravitational mass can be measured.

12.11.76 Understand simple machines and how they provide mechanical advantage. For example, know that a lever is like a balance and that to balance it requires the weights (or forces) applied on each end to be in the inverse ratio to that of their distances from the fulcrum. Thus the mechanical advantage increases with greater distance from the fulcrum.

12.11.77 Understand the principles of air pressure and fluid dynamics. Understand Archimedes' Principle and Bernoulli's Principle. Understand that air pressure decreases as altitude increases. Understand that pressure in a liquid increases as the depth increases. Understand how a hydraulic lift (such as the kind used to raise a car for repairs) confers mechanical advantage.

12.11.78 Understand the universal law of gravitation: that gravitation is a force that every mass exerts on every other mass. The strength of the gravitational attractive force between two masses is proportional to the masses and inversely proportional to the square of the distance between them (inverse square law).

12.11.79 Understand the types of motion such as linear, circular, parabolic, and periodic. Explain and predict motions in inertial and accelerated frames of reference.

12.11.80 Understand that the electrical force is a universal force that exists between any two charged objects. Opposite charges attract, like charges repel. The strength of the force is proportional to the charges, and, like gravity, it is inversely proportional to the square of the distance between the charged bodies.

12.11.81 Understand that between any two charged particles, the electrical force is vastly greater than the gravitational force. Most observable forces such as those exerted by a coiled spring or friction may be traced to electrical forces acting between atoms and molecules.

Grade 11

STANDARD 12E – EARTH SCIENCE

The Earth's Structure

12.11.82 Indicate that the earth's crust is made from mostly igneous and metamorphic materials and was formed as a result of partial melting of part of the mantle rock. Know that there is a thin layer of sedimentary rock on top in many places.

12.11.83 Understand that geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations. Understand that current methods include using the known decay rates of radioactive isotopes present in rocks to measure the time since the rock was formed.

12.11.84 Understand that most scientists believe that the sun, the earth, and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago.

12.11.85 Understand that interactions among the solid earth, the oceans, the atmosphere, and organisms have resulted in the ongoing transformation of the earth system. Understand that we can observe some changes (such as earthquakes and volcanic eruptions) on a human time-scale, but many processes (such as mountain building and plate movements) take place so sporadically or so slowly (over hundreds of millions of years) that we cannot observe them but only infer that they take place from other kinds of evidence.

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STANDARD 12E – EARTH SCIENCE (Continued)

The Earth's Dynamic Processes

12.11.86 Identify the various features of the ocean floor which furnish evidence for plate tectonics: magnetic patterns, age, and topographical features.

12.11.87 Identify the properties of rocks and minerals based on the physical and chemical conditions in which they are formed, including plate tectonic processes.

12.11.88 Understand why earthquakes occur and how scales are used to measure their intensity and magnitude, specifically the Richter and Mercalli scales.

12.11.89 Differentiate between the two main kinds of volcanoes: one kind with violent eruptions producing steep slopes and another kind with voluminous lava flows producing gentle slopes.

12.11.90 Understand that energy enters the systems of Earth chiefly as solar radiation and eventually escapes again as heat.

12.11.91 Understand that incoming solar radiation is either reflected or absorbed.

12.11.92 Understand that non-uniform heating of the earth results in circulation patterns in the atmosphere and oceans that globally distribute heat (in the form of winds and ocean currents).

12.11.93 Understand the connection between the earth's rotation and the circular motion of ocean currents and air pressure centers.

12.11.94 Understand that biomes such as rain forests and deserts are distributed in bands at specific latitudes and how this results from the interaction of wind patterns, ocean currents, and mountain ranges.

12.11.95 Understand that weather (over a short time) and climate (over a long time) result from the transfer of energy and water in and out of the atmosphere. Understand the effects on climate of latitude, elevation, topography (especially the presence of mountains and valleys), and proximity to large bodies of water, and cold or warm ocean currents.

12.11.96 Understand that Earth's climate has changed over time, corresponding to changes in Earth's geography, atmospheric composition, plate movement, and the cyclic changes in the orientation of Earth's axis of rotation and the shape of its orbit around the sun.

Grade 11

STANDARD 12E – EARTH SCIENCE (Continued)

The Atmosphere

12.11.97 Understand the major gases present in the earth's atmosphere, and the percentage which each represents in the composition of the atmosphere (i.e., nitrogen is about 80% and oxygen is about 20%), and that the atmosphere is a mixture, not a compound.

12.11.98 Understand that carbon dioxide increases the greenhouse effect in our atmosphere and that it is produced whenever carbon-containing fuels are burned (e.g., wood, coal, charcoal, oil, natural gas). Understand that removing forests removes trees which absorb carbon dioxide and release oxygen.

12.11.99 Analyze weather conditions of an area, given specific weather data.

Water

12.11.100 Understand that a water table marks the top of the zone of saturation of subsurface materials.

12.11.101 Understand at which places in a river or stream one is likely to find a build up of sediment. Understand why sediments of certain sizes build up in different locations in a stream and how this can alter its course over time. Understand how these processes can, over the course of time, change the location of rivers and streams (e.g., meanders).

STANDARD 12F – ASTRONOMY

12.11.102 Understand and describe the physical characteristics of galaxies and the objects within galaxies (e.g., stars, pulsars, black holes, planets, comets, asteroids). Describe physical characteristics of the sun (e.g., corona, prominences, sunspots, solar flares), and know that solar events can cause phenomena such as auroras.

12.11.103 Analyze the life cycles of stars, and compare stars of different masses.

12.11.104 Know the theory that over 10 billion years ago the universe began in a huge expansion called the Big Bang. Understand that in this event, all matter, energy, space, and time were created as the universe expanded from a single point. Understand that one piece of evidence for this theory is the 3K background radiation.

12.11.105 Understand the Doppler effect with respect to light (red and blue shifts) and sound (e.g., the sound of an approaching train's whistle vs. the sound of the whistle moving away). Understand that astronomers use the Doppler shift to estimate the distance of objects millions and billions of light-years away.

12.11.106 Understand the effects of gravity within the solar system. Understand that the tides are caused by the gravitational interaction among the earth, moon, and sun.

Science – State Goal 13

Grade 11

STANDARD 13A – SAFETY AND PRACTICES OF SCIENCE

13.11.01 Understand basic rules of safety in conducting scientific experiments in a laboratory or in the field.

13.11.02 Understand why experimental replication is essential to scientific claims.

13.11.03 Understand how scientific knowledge, explanations, and technological designs may change with new information.

13.11.04 Understand that scientists must be responsible about how they conduct their experiments.

13.11.05 Determine the degree of accuracy in measurements. Identify possible sources of error in measurement.

STANDARD 13B – SCIENCE, TECHNOLOGY, AND SOCIETY

13.11.06 Analyze scientific breakthroughs in terms of societal and technological effects.

13.11.07 Analyze examples of resource use, technology use or conservation program and make recommendations for improvements.

13.11.08 Analyze careers and occupations that are affected by knowledge of science.

Measurement

13.11.09 Select appropriate scientific instruments and technological devices to perform tests, measure, and collect data.